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Research Article

Relative Physics

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Abstract

The concept of energy is still an open question. Richard Feynman, Nobel prize in Physics, said in his lectures in the 60's that, besides recent developments in Physics, we really don't know what energy is. Other physicists, 'members of energy in the world have pointed out the same difficulty. In this paper, I demonstrate that energy is a relative equivalence inside itself, i.e., there is a compensatory mechanism inside the global relative thermodynamic systems. In other words, in relative thermodynamics, the global relative thermodynamic systems are energy in itself and in the interconnection inside internal and entropy of the system and entropy of its surroundings. This is the universal entanglement, an interconnected relative closed system. Each relative closed thermodynamic system is in interconnection with all relative thermodynamic systems in universe. We can consider levels of energy the c2; maximum gravity or black holes and the Big Bang or the new universe. These singularities are in interconnection with each other. DNA of the new universe is inside the black holes and the rearrangement depends on the way of forward of the new universe, the new Big Bang. I introduce the new Physics, Relative Physics. The key of universe is an update on Einstein s theory of relativity, where the reference is moved to the inside of the global relative thermodynamic system, to the inside of energy.

Keywords: Energy; Universe; Principle of relative equivalence; Interconnected or entangled relative thermodynamic systems; Einstein

Introduction

The concept of energy is still nowadays an open question. Richard Feynman (1918-1988) said that, besides developments in physics, we have no knowledge what energy is. Other physicists have pointed out the same difficulty. The concept of energy is also used in explanations of physiological processes. In this context, the meaning of energy is also an open question.

Historians of science claim that the discovery of the conservation of energy is due to Robert Mayer, Hermann von Helmholtz, James Joule, Ludwig Codling in the middle of 19th century. Coelho in 2009 shows that the discovers of energy discovered a principle of equivalence between physical quantities never connected before. Then, one raises the question whether this idea of equivalence can be useful in the understanding of energy in life sciences.

The inorganic domain has been studied historically since 19th century. The organic domain didn`t have been studied until 2014, when Rocha-Homem shows that Mayer had applied this principle of equivalence to the organic domain. According to Elkan, the discovery of conservation of energy is attributed to Helmholtz. Heiman, Caneva, Coppersmith, among others, attribute this discovery to Mayer. Coelho in 2011 and Rocha-Homem in 2014 put the question about the attribution of this principle, historically and philosophically.

The idea of this principle came from a Mayer`s clinical observation in1840. Mayer observed that the venous blood of the crew in the tropics had a lighter colour than that of people living in colder regions. The confirmation of this observation has been theorized through an explanation by a model for living beings, based on Mayer`s own data and current physiology about the colour of venous blood by Rocha-Homem in 2014.

This model can be outlined in the following fashion. The base of biological phenomenon is the electrogenic sodium-potassium pump. Sodium is pumped out of the cell spending

ATP and a carbon dioxide molecule is produced. Carbon dioxide binds to hemoglobin producing carboxyhaemoglobin, which confers a darker colour to blood, at peripheral capillary level. Carboxyhaemoglobin is transported by the vena cava to the lungs where carbon dioxide swaps over with inhaled oxygen. Oxygen binds to hemoglobin producing oxyhemoglobin which gives the blood a lighter colour. Oxyhemoglobin travels to the heart and is distributed to the entire body via the aorta. At peripheral capillary level, oxygen will enter a new Krebs cycle.

In this way, we atribute to Mayer the credit of the invention of the principle of conservation of energy. Following Coelho in 2009 and 2011, for Mayer energy is an equivalence and that Mayer replaces the principle of conservation of energy by the principle of equivalence [1]. Mayer applied this principle of equivalence to living beings [2-4].

In this research, I am going to demonstrate whether this principle of equivalence can be applied to universe as an interconnected relative closed thermodynamic system as for example living beings in our universe.

Thermodynamic Model of Energy

According to classical thermodynamics, I can construct a hypothetical biological restrictive system and demonstrate logically if this principle of equivalence can be applied. It is important to distinguish between two aspects of equivalence: the equivalent when two things are equal and the equivalence cause-effect when the cause is equal to the effect. But the principle of equivalence in the theory of Mayer is a particular case of equivalence cause-effect, because the effect is multiple and diverse and the cause is unknown.

Suppose a thermodynamic restrictive system, like a molecule, and analyze logically his inner coherence. For this, it is necessary to take attention to some aspects. In living beings, all molecules are constituted by different arrangements of electrons and protons in their atoms. Electros are negative and protons are positive.

The force at the molecular level is the electric force, which is attractive or repulsive. Molecules are in interaction with each other and they collide and break up and rearrange themselves giving another new different molecules.. In consequence, molecules have different energies depending on their particular arrangement of protons or electrons within their atoms.

But, what energy is? For some physicists, energy is a substance. In this case, energy will be a concrete thing like atoms, cells, molecules, etc.

Feynman said that energy is a mathematical principle. In this case, how could we understand molecules with more energy and others with less energy?

I am going to analyze logically this thermodynamic restrictive system.

Ligations of biological systems are ligations of chemical reactions and then, they share thermodynamic characteristics.

In classical thermodynamics, a thermodynamic system where reactions take place is the matter or one region of space limited by a boundary or a hypothetical one. The energy of the rest of the thermodynamic universe is the surroundings. With Einstein`s theory of relativity, E = mc2, energy and matter are equivalents. I introduce relative thermodynamics: in relative thermodynamics, a relative thermodynamic universe is energy of global relative thermodynamic system, system and its surroundings that are interconnected by a hypothetical boundary. Also in classical thermodynamics, systems can be closed, in which only exist interchanges of energy with the exterior; isolated, where there are no changes of energy with the exterior and open, where there are changes of energy and matter with the exterior. In relative thermodynamics, thermodynamic systems are relative closed systems, like, for example, living beings.

Besides a strong intercorrelation between both systems, for methodological reasons, I first analyze the system and then, correlations between system and its surroundings.

Reactions of biological thermodynamic systems occur in general in conditions of constant temperature and pressure.

I am going to suppose by hypothesis, three energies in the thermodynamic system. But, these energies are different ways of saying energy of the system, according to relations between atoms within molecules. They are different from the two stages of each energy, the order stage and the disorder one.

I analyze the different energies in the thermodynamic system.

In a chemical reaction where ligations between atoms of a molecule are formed or break up, there is release or absorption of energy by atoms within the reaction respectively: free atoms, reactants and ligated atoms, products. This variation of energy between the initial stage of free atoms (Ea) and the final stage of ligated atoms (Eb) is called variation of enthalpy of the thermodynamic system (DHsyst) [7]:

DHsyst @ f (Eb-Ea)

Enthalpy is a function of initial and final stages of a reaction, but it is independent from intermediary ones. And it is approximately equal or equivalent to internal energy of these ligations.

The relation between variation of enthalpy (DHsyst) and variation of internal energy (DEsyst), variation of volume (DV) and pressure (P), is given by [6]:

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DHsyst @ DEsyst + P DV

In an exothermic reaction where there is release of energy on the formation of atoms ligations, enthalpy is negative, i.e., energy of ligated atoms (EB) is lower than energy of free atoms (EA); in a endothermic reaction where there is absorption of energy on the breakup of atoms ligations, enthalpy is positive.

The other energy of the system is entropy. Entropy is the free movement of atoms in the thermodynamic system before the formation or after the breakup of atoms ligations. And this free movement of free atoms in the system is called variation of entropy of the thermodynamic system (DS). And entropy increases when free atoms become more disordered.

The relation between variation of enthalpy (DH) and variation of entropy (DS), is called free energy of Gibbs (DG) of a thermodynamic system [7]. It is given by [6]:

DGsyst @ DHsyst - T DSsyst (1)

In this way, each molecule has an own free energy related to variation of his enthalpy or internal energy and his entropy. And this free energy of a thermodynamic system must be negative, (DGsyst<0), i.e., its stage of ligated atoms must be coincident to a minimum of free energy.

For this reason, molecules must cross over barriers of energy to react to each other. The molecule on his stage of free energy minimum, his stage of ligated atoms A1, must cross over a barrier of energy (*Gsys), a stage of free atoms, in order to go forward from this stage A1 to another one A2 crossing by one stage of free atoms A3, i.e., G_{sys}. And this barrier, this stage of free atoms, must be coincident with one minimum of free energy, i.e., it must be negative to faciilty the transition from the stage A1 to the stage A2.

In consequence, the native stage of a molecule corresponds generally to a stage of a minimum of free energy, a negative free energy (DG<0).

We have a first thermodynamic condition necessary for a reaction can occur, DG<0 [6]. And this condition depends on, as we can see in (1), a relation between the variation of enthalpy and variation of entropy of the thermodynamic system.

But, if we consider the global thermodynamic system which is constituted by the system and the surroundings, these two systems are interconnected with interchanges of energy between both systems.The first law of thermodynamics says that total energy of both systems is always constant.

Then, a decrease on enthalpy of the system (DHsyst<0) corresponds to an increase of energy in total system because of an increase of entropy of the surroundings (DS_{sur}>0):

DHsyst @ - T DSsur (2)

By the other side and according to the second law of themodynamics, total entropy, i.e., entropy of the system and of the surroundings, must be positive (DSsyst + DSsur)>0 in order to a reaction can occur. And once again, a decrease of entropy of the system is compensated with an increase of the surroundings in order to satisfy the second law of thermodynamics and the first law of thermodynamics: total energy, i.e., energy of the system and energy of the surroundings, is always constant.

There are two necessary conditions to a reaction can occur:

1. DGsyst<0

2. (DSsyst + DSsur)>0

As these systems are interconnected in the process of a chemical reaction, I can replace (1) by:

DGsyst @ - T DStotal (3)

I can say that a reaction can occur, DG<0, if DStotal>0.

According to this correlation, I analyze the conditions of logical possibility in the reactions, exothermic and endothermic ones.

In an exothermic reaction where there is release of energy in the formation of ligations of atoms of molecules, enthalpy of the system is negative, DHsyst<0. The probability of this reaction can occur, DGsyst<0, includes three situations, (but it is important to say that we talk in modules for its energy):

1. Entropy of the system is negative (DSsyst<0). And this is because as there is formation of ligations of atoms of molecules, variation of entropy can be negative. Then and by the reaction in (1), the reaction can only occur, DGsist<0, if enthalpy of the system (DHsyst) decreases but being higher than DSsyst. But for the other side, the other necessary condition to a reaction can occur is that DStotal>0, and the first law of thermodynamics says that total energy, energy of the system and of the surroundings, is always constant. How to conciliate these two necessary conditions and the two laws of thermodynamics in a system where enthalpy and entropy are both negative?

The solution is given by (2), i.e., a decrease of the enthalpy of the system is compensated by an increase of the entropy of the surroundings. By the other side, the reaction in (3) is confirmed, i.e., a reaction can occur, DGsyst<0, if DStotal>0.

2. Entropy of the system is positive (DSsyst>0). In these conditions and according to (1) a reaction can only occur, DG<0 if entropy of the system is lower than its enthalpy. And entropy of the system cannot increase because atoms are very ligated. Then, there will be a compensatory increase of entropy of surroundings and the laws of thermodynamics are satisfied.

3. Entropy of the system is $S_{sys} = 0$ or S=¥. In these particular cases, enthalpy of the system, according to (1), decreases to minimum or increases to maximum respectively, and according to (3), there will be a compensatory increase to maximum of entropy of its surroundings. In these situations, the system collapses. Then, in order to laws of thermodynamics be satisfy, enthalpy of the system must increase, entropy of the system must decrease and according to (3), there will be an increase of the entropy of its surroundings. This is an endothermic reaction.

In an endothermic reaction where is absorption of energy on the breakup of atoms of molecules, enthalpy is positive (DH>0). This reaction can occur, DGsyst<0 and according to (1), if entropy of the system decreases, and if DStotal>0 and the first law of thermodynamics is satisfied. As entropy of the system must decrease, in order to satisfy (2) there will be a compensatory increase of entropy of its surroundings. (DSsur>0).

There are two particular cases, in endothermic and exothermic reactions respectively: when enthalpy of the system is zero (H=0) or infinite (H=¥). In these conditions, according to (1) or (2), there will be a compensatory maximum increase of entropy of surroundings, i.e., it points to infinite, but laws of thermodynamics are satisfied. In endothermic reactions, in order to a reaction could occur, G<0 and $S_{total}>0$, and laws of thermodynamics are satisfied, Hsys and S_{sys} must increase but in order to $G_{sys}<0$, free energy of the system, i.e., an increase of H_{sys} is compensated by a decrease of S_{sys}, and as seen in (3), there will be a compensatory increase of entropy of surroundings.

In this analysis, it is confirmed a relation of both systems seen in (3), i.e., a reaction can occur, DGsyst<0, if DStotal>0, and there is a compensatory mechanism in system and between both systems in order to satisfy the laws of thermodynamics. In other words, the global relative thermodynamic system has a compensatory mechanism between enthalpy or internal energy of the system and entropy of the system, i.e., free energy of the system, and entropy of its surroundings, in order to satisfy the two laws of thermodynamics. There is an equivalence in the system and between both systems. With Einstein`s theory of relativity, $E=mc^2$, there is an equivalence between matter and energy. In consequence, this equivalence is relative. But, we need to reformulate the meaning of relativity: we move the reference to the insight of global system, of energy as a relative equivalence.

As I have already said, what happens at molecular level has consequences in all organism. In consequence, each particle has its own free energy which must be negative. In classical thermodynamics, particles can be considered as isolated systems, but as they are interconnected with other particles in relative thermodynamic universe, we truly cannot say this. In relative thermodynamics, relative thermodynamic universe is constituted by interconnected relative closed systems. Each particle is a relative thermodynamic closed universe, like for example a quark, and quarks are in protons and neutrons and these with electrons are in atoms, atoms are in molecules, etc. Organisms like living beings and all relative closed thermodynamic systems as for example quarks, etc, are constituted by several interconnected relative closed systems and they share the same thermodynamic characteristics as those described to molecules.

A relative thermodynamic system is an interconnected relative closed system with maximum, minimum and zero points, singularities which are hypothetical boundaries where entropy of surrondings is maximum, i.e., it points to infinite. In other words, each relative thermodynamic system begans at zero point, Big Bang, where energy of system becomes organizing as a interconnected relative closed system, points to a maximum, c^2, to a minimum, black holes or maximum gravity, where collapses, to another zero, a new relative thermodynamic system, etc. And these singularities are relative equivalences at different levels and interconnected.

But, can the principle of equivalence of Mayer be applied to this thermodynamic model? For Mayer, equivalence is an equivalence cause-effect where the cause is equal to the effect. The effect is multiple, diverse, and the cause is unknown. And, the equivalent where one thing is equal to another is coincident to the equivalence cause-effect. In other words, we don`t need to see what is not seen like for example the transformation of potential energy (mgh) into cinetic energy ($1/2\ mv^2$) as we learn in textbooks of physics: mgh is equal or equivalent to ½ mv^2.

But in the principle of equivalence of Mayer it is not included this meaning of relative equivalence. In consequence, we need to reformulate the meaning of the principle of equivalence of Mayer: a relative equivalence as a compensatory mechanism within system and in global system in order to satisfy the laws of thermodynamics, i.e., an equivalence in itself. As I have already said, Einstein in his theory of relativity, $E=mc^2$, says that energy and matter are equivalents and that this equivalence is relative. In other words, a small increase in mass or matter is equivalent to a great increase of energy. But, as I have already said, we need to reformulate the meaning of relativity, i.e., the reference is moved to the insight of global system, energy as a relative equivalence where the reference is in its insight.

As internal energy of the system (E_{sys}) is equivalent to enthalpy of the system (H_{sys}), Energy (E) as an equivalence in itself is given by:

$$E =\sim [(E_{sys} - S_{sys}) - S_{sur}]\ c^2$$

or

$E =\sim (Esys =\sim - Ssur)\, c^2$

Once again, the equivalence in itself is a relative equivalence. For example, a decrease of enthalpy or internal energy of the system is equivalent to as increase of entropy of the surroundings.

Then, this principle of equivalence in itself can be applied to all relative thermodynamic systems in our universe, being living beings an example. As a universe is constituted by interconnected relative closed systems and universe is an interconnected relative universes, then:

$$E =\sim \sum_{0}^{+-\infty} [(E_{sys} - S_{sys}) - S_{sur}]\, c^2$$

$$E =\sim \sum_{0}^{+-\infty} [(E_{sys} =\sim - S_{sys}) =\sim -S_{sur}]\, c^2$$

or

$$E =\sim \sum_{0}^{+-\infty} (E_{sys} =\sim - S_{sur})\, c^2$$

Conclusion

The concept of energy is still nowadays an open question. Richard Feynman and other physicists didn`t know what energy really is.

This concept is also used in explanations of physiological processes. In an attempt to give an answer to this question, we need to analyze the concept of energy. Robert Mayer invented the principle of conservation of energy in 1840. This discovery was made possible because a medical observation by Mayer in 1840. Mayer, a very unusual physician, went to Java, Indonesia, as the medical doctor of the ship. When arrived, he was surprised because he observed, doing phlebotomy, that the colour of venous blood in the tropics was lighter than in the colder regions of the globe.

The concept of energy in inorganic domain have been studied historically since 19th century but not the organic one. Coelho [8] remarks that for Mayer, energy is an equivalence in inorganic domain. He claims that Mayer and other physicists replace the principle of conservation of energy by the principle of equivalence [1]. Rocha-Homem [2] showed that Mayer had applied this principle of equivalence to biological domain. This was made by an explanation with a model for living beings based on Mayer`s own data and current physiology about the colour of venous blood.

But, can this principle of equivalence be applied to all thermodynamic systems in universe, being living beings an example in our universe? In an attempt to answer to this question, I elaborated a thermodynamic model of energy for thermodynamic systems, which give us an understanding of energy. I have analyzed thermodynamic process in closed systems like molecules.

What happens in terms of thermodynamics in the level of the molecules has consequences in global organism as constituted by quarks, protons, electrons, atoms, cells, molecules, etc., being each particle a relative universe. As we have seen, a reaction can occur if entropy increases. This is the condition imposed by the second law of classical thermodynamics. But, how can the organization of living beings be understood? In classical thermodynamics, the answer is that the second law of thermodynamics doesn't apply to all systems but only to the isolated ones [9]. Living beings are open systems where organization can increases by an excess of disorganization in the surroundings [9].

Living beings are open thermodynamic systems, which have the capacity of transformation of the exterior energy to their organization. They are constituted by molecules, which are isolated systems that go forward to disorganization by the increases of entropy. In the opposite side, living beings organize by the increase of disorganization or entropy of the surroundings. But, the second law of thermodynamics is satisfied because entropy, of the isolated system and surroundings as a globalitys as an isolated system, increases [9]. In relative thermodynamics, there is a compensatory mechanism in the system and between both systems. Then, living beings organize by an increase of entropy of the surroundings and a compensatory decrease of entropy in the system, by a compensatory mechanism between enthalpy or internal energy and entropy of the system, i.e., free energy of the system. And free energy of the system must be negative.

Once again, in living beings, the first and the second laws of thermodynamics are satisfied. And how organize quarks, atoms, cells, molecules, etc.? Each particle is a relative universe, an interconnected relative closed system and each particle has its own free energy that must correspond to a minimum of free energy of system and there is a compensatory mechanism between system and its surroundings.

In textbooks of physics, energy (E) is the sum of potencial energy (E_p) and cinetic energy (E_c).

By the equivalence of Mayer:

$Ep =\sim Ec$

and by equivalence in itself:

$$\sum_{0}^{+-\infty} [(E_{sys} - S_{sys}) =\sim - S_{sur}]\ c^2$$

or

$$\sum_{0}^{+-\infty} (E_{sys} =\sim - S_{sur})\, c^2$$

In the theory of Mayer, the cause is equal or equivalent to the effect, but it is not included this meaning of relative equivalence.

Then, we need to reformulate the principle of equivalence of Mayer and then it can be applied to all relative thermodynamic systems in relative universe being living beings an example in our universe. Can this principle of equivalence in itself, be applied to universe?

In this thermodynamic model of energy, a relative universe is an interconnected relative closed system, a relative equivalence, with maximum, minimum and zero points, hypothetical boundaries which correspond to singularities, points where entropy of surroundings is maximum. c^2 is a relative equivalence in a maximum hypothetical boundary of a universe, a singularity, and maximum gravity is a relative equivalence, a singularity where entropy of surroundings is maximum, in a minimum hypothetical boundary of an universe, a black hole. Big bang is the zero point, a singularity where entropy of surroundings is maximum and where an universe becomes organizing as a relative closed system. These points are interconnected and in different levels, then a relative universe is an interconnected relative closed system that begins in Big Bang and points to a maximum, then to a minimum, etc. In other words, a universe begins as a Big Bang that is relative equivalent to a maximum, c2, that is relative equivalent to a minimum, black hole and then collapses and that is relative equivalent to another and different Big Bang, etc., a new relative universe.

A universe is energy as an equivalence relative, equivalence in itself, a relative thermodynamic universe, that organizes as an interconnected relative closed systems. Its constitution depends on how energy organize as an interconnected relative closed system.

In consequence, this principle of relative equivalence, equivalence in itself, can be applied to all systems in a relative universe and to universe as interconnected relative universes.

For example, our observable universe is a relative closed thermodynamic system constituted by relative thermodynamic systems like stars, planets, within galaxies, etc. and by quarks, protons, neutrons, electrons, within atoms, molecules, etc. Quarks are particles, relative closed systems unobservable in itself that are in our universe, etc.

Relative physics applies to all things in universe. In science, in astronomy, its main problems, dark energy and parallel universes, are solved. Dark energy is a new Big Bang, a new universe. Paralell universes are different ways of rearrangement of the universe. Fiction and really are diferent points of view of universe, according to the forward of the universe.

In quantum mechanics, the Nobel prize in Physics 2022 had demonstrated the enthangled universe to the subquantum universe and proved the violation of Bell's theory: universe doesn't hidden any variable, any probability. In this research, I demonstrate the universal entanglement.

In internal medicine, its main problems, cancerous diseases, are solved New Genetics need to rearrange the nucleotides of the new DNA that are encoded in the black holes, the maximum entropy of surroundings, of the old universe. The language of new Physics, Relative Physics is the new Logics: an interconnection between inductive and deductive logics. And can we understand the meaning of energy?

There are many definitions of energy. This definition of energy as an equivalence has been given by some physicists, but this equivalence is between heat and work [10-12]; Allen e Maxwell [13,14]. For Fermi, energy is a substance. How can we conciliate things so different? [15-35].

In this analysis, I have demonstrated that there is an equivalence in energy itself, in the system and between both systems. But, this is an equivalence different from the one pointed out by some physicists as an equivalence between heat and work.

Then, energy is an equivalence in itself where laws of thermodynamics are satisfied. But, we need to update laws of thermodynamics:

First law: Energy of global closed thermodynamic system is always constant; **Second law or Einstein's law:** Entropy of its surroundings is always increasing. These are the relative thermodynamic laws.

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Competing Interests

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References

1. Coelho LR (2020) On the energy concept problem: Experiments and interpretations. Found Sci 26: 607-624.
2. Rocha-Homem T (2014) Energia e medicina: Mayer e Helmholtz [Faculdade de Ciências da Universidade de Lisboa PhD dissertation].
3. Rocha-Homem T (2015) Robert Mayer: Conservation of energy and venous blood colour. Adv Hist Stud 4: 309-313.
4. Rocha-Homem T (2022) The concept of conservation and transformation of energy and venous blood colour: an invention by Robert Mayer. Current Innovations in Medicine and Medical Science 9: 1-9.
5. Brown G (1999) The Energy of Life. London: HarperCollins Publishers.
6. Stayer L (1975) Biochemistry. New York: W H Freeman and Company.
7. Smith E (1973) Brian fundamentos de termodinâmica química. Coimbra. Editors Almedina.
8. Coelho R (2009) on the concept of energy: how understanding its

history can improve physics teaching. Sci Educ 18: 961983.

9. Peixoto JPA (1985) aspectos da termodinâmica e da energética dos seres vivos. Faro: textos escolares universitários.

10. Voigt W, Leipzig TI (1903) G j Goschensche.

11. Preston T (1919) The theory of heat. Educ Rev Cotter.

12. Müller P (1926) Lehrbuch der Physik. I parte. 11th ed. Braunschnveig. Friedr. Vieweg Sohn.

13. Allen HS, Maxwell RS (1962) A textbook of heat. London: Macmillan.

14. Fermi E (1956) Thermodynamics. New York: Dover.

15. Alonso M, Finn EJ (1996) Physics.

16. Arons AB (1999) Development of energy concepts in introductory physics courses. Am J Phys 67: 1063-1067.

17. Barbosa JPV, Borges AT (2006) O Entendimento dos Estudantes sobre Energia no início do Ensino Médio. Caderno Bras Ensino Fis 23: 182-215.

18. Borgnakke C, Sonntag RE (2009) Fundamentals of thermodynamics. Hoboken, NJ: John Wiley & Sons.s

19. Braunwald E (2001) Harrison's principles of internal medicine. 15th Edition. New York: McGraw-Hill.

20. Caneva K (1993) Robert Mayer and the conservation of energy. Princeton: Princeton University Press.

21. Coelho RL (2006) O. Conceito de energia. Passado e sentido. Aachen: Shaker Verlag Gmbh/Instituto Rocha Cabral.

22. Coelho R (2011) Lopes on the concept of energy: eclecticism and rationality, Abstract of the IHPST Conference. Thessaloniki.

23. Coopersmith J (2010) Energy. The subtle concept. Oxford: Oxford University Press.

24. Einstein A (1989) The collected papers of… Vol. 2. The Swiss years: Writings, 1900-1909. Princeton: Princeton University Press.

25. Elkana Y (1974) The discovery of the conservation of energy. London and Southampton: Hutchinson Educational.

26. Farber E (1954) The colour of venous blood. Isis 45: 3-9.

27. Feynman RP, Leighton RB, Sands M, Treiman SB (1964) The Feynman Lectures on Physics. The Feynman Lectures on Physics. Physics Today 17: 45-46.

28. Gartenhaus S (1975) Physics. Basic principles. Vol. 1. New York: Holt, Rinehart & Winston.

29. Guyton A, Hall J (2006) Textbook of medical physiology. 11th Edition. Philadelphia: Elsevier.

30. Kittel C, Knight WD, Ruderman MA, de Física de Berkeley C (1970) Mecânica. Volume 1. S Paulo: Editora Edgard Blucher Ltd.

31. Heimann PM (1974) Conversion of forces and the Conservation of Energy. Centaurus 18: 147-161.

32. von Helmholtz H (1882) Wissenschaftliche Abhandlungen I. Leipzig: Barth.

33. Mayer JR (1842) Bemerkungen uber die Krafte der unbelebten Natur. Ann Chem Pharm 42: 233-240.

34. Mayer JR (1845) Die Organische Bevegung in ihrem Zusammenhange mit dem Stoffwechsel. Heilbronn Mayer.

35. Singh J (1961) Great ideas and theories of modern cosmology. New York: Dover publications, Inc.