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“ARROW OF TIME” – A HUNDRED-YEAR-OLD PHANTOM

Research article

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Abstract

The work is devoted to the problem of harmonization of the philosophical foundations of dynamics and thermodynamics. The laws of mechanics are reversible, which seems to contradict the condition of the increase in entropy in a closed thermodynamic system, which follows from the second law of thermodynamics: it turns out that different parts of physics interpret the concept of time differently. At the beginning of the 20th century, the problem of the contradiction between dynamics and thermodynamics attracted close attention; now interest in it has noticeably waned.

The basis for solving this problem is the ontological principle of the unity of the world. The contradiction under discussion exists in our descriptions of nature, and not in nature as such: Nature is one in its essence, and cannot have logically contradictory properties. The mistake is the violation of the law of identity in the process of reasoning, leading to a “contradiction” between mechanics and thermodynamics: the 2nd law was introduced axiomatically in the construction of thermodynamics; then it was substantiated within the framework of statistical physics by Maxwell and Boltzmann based on the theory of probability; for any system there is a non-zero probability of its violation. Thus, when the 2nd beginning is reduced to dynamics, it is treated as a statistical law, and then requirements are made to it as to a dynamic law. The “contradiction” between dynamics and thermodynamics is a consequence of this illegal (for an essentially probabilistic statement) status of the 2nd principle, which imposes a ban on some dynamically possible states.

Keywords: time, philosophy of time, second law of thermodynamics, irreversibility, philosophy of science, Eddington.

«СТРЕЛА ВРЕМЕНИ» – ФАНТОМ СТОЛЕТНЕЙ ДАВНОСТИ

Научная статья

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Аннотация

Работа посвящена проблеме согласования философских оснований динамики и термодинамики. Законы механики обратимы, что как будто бы противоречит вытекающему из второго закона термодинамики условию возрастания энтропии в замкнутой термодинамической системе: получается, что разные части физики по-разному трактуют понятие времени.

Основа для разрешения этой проблемы – онтологический принцип единства мира. Обсуждаемое противоречие существует в наших описаниях природы, а не в природе как таковой: Природа едина по своей сути, и не может обладать логически противоречащими друг другу свойствами. Ошибкой является нарушение закона тождества в процессе рассуждений, приводящих к «противоречию» между механикой и термодинамикой: 2-е начало было введено при построении термодинамики аксиоматически; затем оно было обосновано в рамках статистической физики Максвеллом и Больцманом с опорой на теорию вероятности; для любой системы существует не равная нулю вероятность его нарушения. Таким образом, при редукции 2-го начала к динамике оно трактуется как закон статистический, а затем к нему предъявляются требования как к закону динамическому. «Противоречие» между динамикой и термодинамикой – следствие этого неправомерного (для вероятностного по своей сути утверждения) статуса 2-го начала, что и налагает запрет на некие динамически возможные состояния.

Ключевые слова: философия времени, Эддингтон, второе начало термодинамики, необратимость, философия науки.

Introduction

This paper is devoted to the problem of relation between reversible and irreversible processes in physics. The problem is posed in connection with the second law of thermodynamics: from the laws of mechanics it follows that entropy is constant, whereas the second law of thermodynamics requires the entropy to increase. This problem (the significance of which goes far beyond physics) is discussed in a great number of papers (for example, in many books of Nobel prize-winner I. Prigogine [1], [2], [3] as well as in his Nobel lecture (1980)). G.A. Martynov wrote in his paper [4, P. 1121]: “In the beginning of this century it (the problem of contradiction between dynamics and thermodynamics due to the increase of entropy) attracted much attention; nowadays, there is a loss of interest in it, and not because the problem was solved, but rather because everyone got used to the thought that it is impossible to solve it. I do not think, however, that this pessimism is warranted”.

As a result, quasi-philosophical arguments about the “arrow of time” [5], which “sets the 2nd law of thermodynamics” (the irreversibility of time is allegedly associated with an increase in entropy [2]), have become widespread.

Main results

Sharing Martynov’s opinion, we, in our turn, formulate the following statements:

The discussed contradiction exists in our descriptions of nature, but not in nature itself. Nature is a single entity that cannot possess contradictory features. Correspondingly, if we have contradictory descriptions of nature, at least one of the descriptions has a logical error.

Therefore, in an attempt to solve the posed problem, one should focus on a thorough logical analysis of the relationship between the basics of mechanics and thermodynamics in order to find the hidden logical mistake that leads to the seeming contradiction, rather than try to apply methods of mathematical physics.

In our opinion, the logical mistake here is that the second principle of thermodynamics is given the status of law. A law is a statement, which is true always, and everywhere, under any conditions. The second principle of thermodynamics, however, was deduced on potential grounds, and in any system there is a probability that it will be violated. The contradiction between dynamics and thermodynamics is a consequence of the unrightfully given status of the second principle (which is probabilistic in essence), and because of this status certain dynamically possible conditions are.

This prohibition becomes an absolute fact of adopting the status of law for probabilistic. This can be illustrated by the following situation: all inhabitants of the Earth participate in a lottery with a single win. The probability of a win is so low that everyone takes it to be nil. Thus, a “contradiction” may arise between the statements that no one has a chance to win and somebody is sure to win.

The explanations statements formulate above are discussed below.

An irreversible process in thermodynamics is a process that increases entropy: the initial conditions cannot be regained. In a great number of papers, The Second Principle is treated as a universal law applicable to data distribution of any nature. According to this approach, Information values are calculated by distribution of certain parameters and then interpretation is implemented in terms of increase/decrease of ordering, etc. [6], [7], [8], etc.

Let us consider a simple computer model of a cell automate (fig. 1), which is commonly used to illustrate statistic regularities of thermodynamic processes. We shall model in this case.

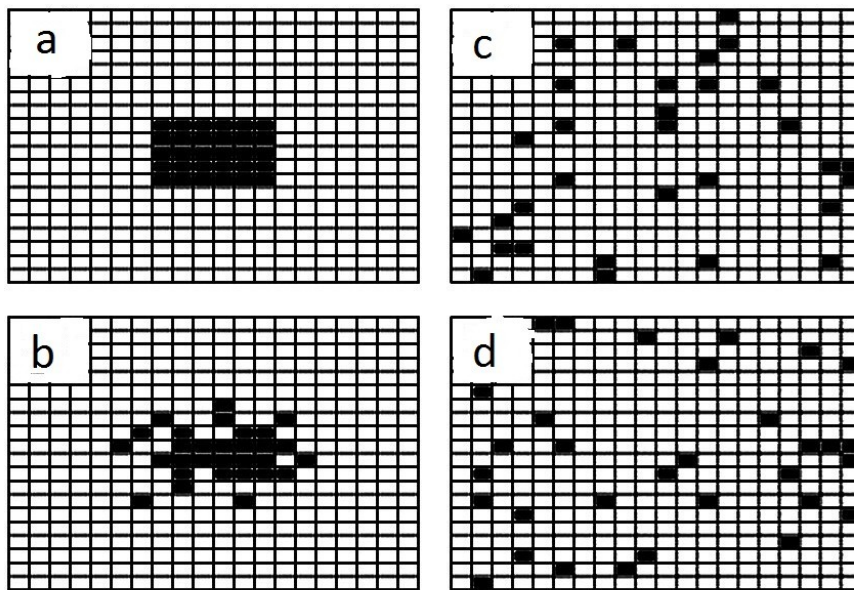


Figure 1 - Computer simulation of diffusion:
a-d – stages of the process

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The beginning of the process is shown in Fig 1(a): on a microscopic level (in the model this is the level of individual cells; or molecules, Brownian particles, etc. in nature) we have a distribution of parameters (X and non-X) in space. The general pattern of a drop of material X in the environment is seen only macroscopically. Let us now set the algorithm for the process to develop: with every temporal quantum, a randomly chosen particle moves to an adjacent empty cell (if any). In due course we will have the patterns shown in Fig. 1(b), 1(c) and so on. This agrees fairly well with the real processes: a drop of ink would dissolve in water, and gas molecules would tend to fill up the entire volume.

Note what the difference between the systems shown in Fig 1(a) and Fig (b - d) exists only in a macroscopic level; microscopically, X is distributed in a different way, no more. The distribution in 1(a) does not differ basically from the distribution in 1(d), and if we follow the path a – b – c – d in opposite direction, we shall the 1(a) distribution again. The state 1(a) is privileged only in terms of a macroscopic description, which, in turn, exists only in sensual perception of an observer, whereas nature consists of atoms and energetic fields. The transition from 1(b) to 1(c) or 1(d) occurs as rarely as the transition

from 1(b) to 1(a), but a macroscopic observer does not fix the difference between 1(b – d) (and between a large number of other states of a system). All these distributions are called by a common name “mixture” or “chaos”, and opposed to “order” (1(a)). Having singled out in our numerical experiment, conditionally speaking, one (1a) of 10^n equiprobable states, we will certainly see, in accordance with the probability theory, that this unique state is replaced by some other one and does not reappear for a very long time. In the end, it will nevertheless arise: within 10^n time intervals. In the theory of thermal processes, this extremely low probability can, of course, be neglected. At this level of description, thermodynamics is extremely efficient, allowing huge dynamic descriptions to be replaced by a few macro variables. However, when analyzing the relationship between dynamics and thermodynamics at the level of individual particles, approximated by sets with a finite number of elements, even a vanishing small probability of the system returning to its original state is of fundamental importance, in the sense that the mystical ban on some states of the dynamic system disappears, from the point of view of thermodynamics having less entropy. In probabilistic terms, the statement of the 2nd law of thermodynamics about the steady increase in entropy loses its mystery and sounds almost like a tautology: more probable processes occur with a greater probability. In fact, within the framework of mechanics, irreversible processes can be detected: thus, following the pattern of the “arrow of time” one can introduce an “arrow of space” based on the fact that gravity on the Earth is always directed towards its center (after all, no one considers the fact that stones roll spontaneously only downhill as a violation of the symmetry of the equations of mechanics!).

Conclusion

Thus, the “problem” of matching dynamics and thermodynamics turns out to be a pseudo-problem based on the violation of the logical law of identity. The solution to the “problem” is so simple that it is difficult for the authors to imagine that no one has thought of it for a century and a half; however, we do not know of publications where the resolution of this “problem” before 1997 (the date of our first publication on the topic under discussion [9]; see also [10]) would be explicitly given.

Конфликт интересов

Не указан.

Рецензия

Все статьи проходят рецензирование. Но рецензент или автор статьи предпочли не публиковать рецензию к этой статье в открытом доступе. Рецензия может быть предоставлена компетентным органам по запросу.

Conflict of Interest

None declared.

Review

All articles are peer-reviewed. But the reviewer or the author of the article chose not to publish a review of this article in the public domain. The review can be provided to the competent authorities upon request.

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