

# The Field Approach to Thermodynamics

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The concept of thermodynamic fields is introduced, and a mathematical apparatus for its description is proposed. Such an approach enables us to shed new light on a number of problems; for instance, on the second principle of thermodynamics, Planck's formula, and Heisenberg's uncertainty principle.

*"A growing number of scientists believe today that the very foundations of present-day thermodynamic theories should be reexamined and perhaps modified. The constant search towards better thermodynamic theories is not merely a logical necessity, but is mainly due to the failure of classical, statistical and relativistic thermodynamics to solve and eliminate the existing problems, inconsistencies and paradoxes inherent in present-day thermodynamic theories..."*

*-- The preface of the 1969 International Symposium on Thermodynamics (Stuart, Gal-Or and Brainard 1970)*

## 1. Introduction

When one reads text books on thermodynamics for the first time one feels like he is reading a scientific paper written in the 18<sup>th</sup> century. Bulky description of the initial ideas, absence of clear distinction between concepts of heat, temperature and internal energy involved in the exact difference between the system and its exterior, all these features essentially hinder the understanding until the realization comes that this is just a collection of experimental facts, a block of clay not reduced to the form of plates and dishes necessary for the housewife.

Maxwell's electrodynamic ideas were much more fortunate than his thermodynamic ones. Electrodynamics quickly became an accurate science and yielded plentiful fruits.

Why did this not happen with thermodynamics although the caliber of the scientists who devoted their life to thermodynamics was not any the less?

Certainly there are many causes of this and they are different. Let us make a supposition concerning cognition side of the problem.

In the electrodynamics, the electron was detected rather quickly. The concept of current was introduced as charged flow and this became a powerful incitement to the development of the theory and attached clear physical meaning to the concept of field.

Until recently the concept of thermodynamic charge has not been introduced, but instead the not very transparent idea of a particle was introduced and instead of an inductively constructed image of field they talk about an ensemble of particles which is an amalgam composing a "system" which interacts with its "compliment" – the rest of the universe.

We must admit that a stochastic description of the ensemble not only did not make the problem more transparent, but even hindered understanding of the problem's essence. In quantum mechanics it has led us into a blind alley of misunderstanding. Thus the slogan: "I believe because this is absurd" has become the oath of loyalty in modern mainstream physics.

The second cause of modern thermodynamical problems is the apparent reluctance to recognize the fundamental character of the Brownian particle movement. You see, the fact that Brownian particle movement time is proportional, not to the traversed

path, but to its square immediately differentiates this type of movement from the concepts of traditional mechanics. The physical analysis of the problem was changed to the probabilistic description and the purely groundless changing of the mean for the dispersion. But if we can attach a very understandable meaning to the mean, then what physical meaning can be given to dispersion, which characterizes the deviation from the mean?

The aim of this article is to formulate a field concept for thermodynamics. Mechanic dimensions for the concepts of the heat and the temperature are introduced, the particle's spin is considered as the charge of the thermodynamic field. The principle thermodynamic assertions are formulated in these terms.

## 2. Necessary Mathematical Apparatus

The aim of this section is to formulate a mathematical instrument for a deterministic description of the movements in which the time of movement time is proportional, not to the transversed path, but to its square.

In mathematical texts, when the concept the of vector product in a space with polar basis  $\mathbf{i}, \mathbf{j}, \mathbf{k}$  is defined, an equality which is considered obvious is used (see [1] for instance):

$$\mathbf{j} \times \mathbf{k} = \mathbf{i}, \quad \mathbf{k} \times \mathbf{i} = \mathbf{j}, \quad \mathbf{i} \times \mathbf{j} = \mathbf{k} \quad (1.1)$$

One cannot agree with it. These equalities are not only not evident, but they are absurd because they equate objects of different mathematical nature: pseudovectors stand in the left hand sides of (1.1) and polar vectors in the right hand part. This problem was discussed in the paper [2]. There it was proposed to introduce unit pseudovectors  $\mathbf{l}, \mathbf{m}, \mathbf{n}$  as the right hand sides in (1.1). In addition to the initial space  $X$  with polar basis  $\mathbf{i}, \mathbf{j}, \mathbf{k}$ , whose points were denoted as  $x = (x_1, x_2, x_3)$  and radius-vector as:

$$\mathbf{r} = \mathbf{i}x_1 + \mathbf{j}x_2 + \mathbf{k}x_3, \quad (1.2)$$

$$|\mathbf{r}| = \sqrt{x_1^2 + x_2^2 + x_3^2},$$

a new space  $Y$  with axial basis  $\mathbf{l}, \mathbf{m}, \mathbf{n}$ :

$$\mathbf{l} = \mathbf{j} \times \mathbf{k}, \quad \mathbf{m} = \mathbf{k} \times \mathbf{i}, \quad \mathbf{n} = \mathbf{i} \times \mathbf{j}. \quad (1.3)$$

and radius-vector

$$\mathbf{R} = \mathbf{l}y_1 + \mathbf{m}y_2 + \mathbf{n}y_3 \quad (1.4)$$

where

$$y_1 = x_2x_3, \quad y_2 = x_3x_1, \quad y_3 = x_1x_2,$$

$$|\mathbf{R}| = \sqrt{y_1^2 + y_2^2 + y_3^2}.$$

Thus one obtains the correct and transparent concept of the vector product as a tensor transmitting vectors from the space  $X$  with polar basis  $\mathbf{i}, \mathbf{j}, \mathbf{k}$  into the  $Y$  space with axial basis  $\mathbf{l}, \mathbf{m}, \mathbf{n}$ , where value and direction coincide with  $\mathbf{i}, \mathbf{j}, \mathbf{k}$ . As a second step one can define the vector product in the new space. It will transmit the pseudovector basis into the polar one.

This last helps to clarify one point in classic mechanics in addition. The problem is that working in polar basis we cannot define concept of the vector angle  $\phi = (\phi_1, \phi_2, \phi_3)$  because  $\phi$  must be a pseudovector. The way out is found when the modulus  $|\phi|$  is considered initially, its time derivative is calculated and only after that, the angular velocity  $\omega = (\omega_1, \omega_2, \omega_3)$  is projected on the coordinates. Its pseudovector character is mentioned later in the addition [3]. But we cannot describe angular velocity as polar vector  $\omega = \mathbf{i}\omega_1 + \mathbf{j}\omega_2 + \mathbf{k}\omega_3$ . Our approach helps to avoid this problem. Actually, the vector angle is naturally defined as

$$\phi = \mathbf{l}\phi_1 + \mathbf{m}\phi_2 + \mathbf{n}\phi_3 \quad (1.5)$$

Then the angular velocity is

$$\omega = \frac{d\phi}{dt} = \mathbf{l}\omega_1 + \mathbf{m}\omega_2 + \mathbf{n}\omega_3 \quad (1.6)$$

Here  $\phi_1$  is understood as relating to the rotation angle in the plane defined by vector  $\mathbf{l} = \mathbf{j} \times \mathbf{k}$ . Correspondingly  $\omega_1$  is the projection of  $\omega$  on this plane. Other projections are understood in the same way. One can introduce Euclidian norm

$$|\phi| = \sqrt{\phi_1^2 + \phi_2^2 + \phi_3^2} \quad (1.7)$$

in the space  $\Phi$  with points  $\phi = (\phi_1, \phi_2, \phi_3)$ . One can also directly verify that  $\Phi$  is a Cartesian space. If we want to return to the space with polar basis  $\mathbf{i}, \mathbf{j}, \mathbf{k}$  we can do this in the following way.

$$\mathbf{n} \times \mathbf{m} = \mathbf{i}, \quad \mathbf{m} \times \mathbf{l} = \mathbf{j}, \quad \mathbf{l} \times \mathbf{n} = \mathbf{k}. \quad (1.8)$$

Such definition is possible because polar vectors stand in the left and right hand parts of (1.8) and the actual coordinates have no dimensionality. The equality (1.8) would not be possible if the basis coordinate vectors  $\mathbf{i}, \mathbf{j}, \mathbf{k}$  had a dimension, for instance, if they were of unit length, in this case being normal vectors to these planes. Let us note that although the points in the new space  $Y$  are characterized by six coordinates, the initial three corresponding to three dimensional space  $X$ , and we do not leave three dimensional space because 3 additional constrains are put on the  $x$  points which define the  $y$  points. For instance, the definitions of the two points  $y_1 = (x_2, x_3)$  and  $y_2 = (x_1, x_3)$  contain the

same coordinate  $x_3$ . But although the unique point  $y = (y_1, y_2, y_3)$  corresponds to any point  $x = (x_1, x_2, x_3)$  and the unique trajectory  $y(t)$  corresponds to any trajectory  $x(t)$  the inverse assertion is invalid: a family of trajectories in  $X$  corresponds to each arbitrary trajectory in  $Y$ .

This fact explains some paradoxes in quantum mechanics: the dual character of the concepts of wave and particle, the capability of an electron to be at different space points at the same time etc. The cause is that trajectories in  $X$  space turn out to be twisted. The above principle can be applied to rotation spaces  $\Phi$  and  $\Psi$ : rotation in  $\Phi$  defines only one rotation in  $\Psi$ , the inverse assertion is invalid.

The movement of a ball or a bullet is an example of movement in spaces  $X$  and  $\Phi$ . The movement of a Brownian particle or an electron in an atom is an example of movement in spaces  $Y$  and  $\Psi$ . Accurate investigation of physical causes of these different types of movement must be done later.

Let us explain this by calculating the velocity in  $Y$  by differentiating equality (1.4) with respect to time:

$$\begin{aligned} \frac{d\mathbf{R}}{dt} &= \mathbf{l} \frac{dy_1}{dt} + \mathbf{m} \frac{dy_2}{dt} + \mathbf{n} \frac{dy_3}{dt} = \\ &= \mathbf{l}(x_2v_3 + x_3v_2) + \mathbf{m}(x_1v_3 + x_3v_1) + \mathbf{n}(x_1v_2 + x_2v_1) \end{aligned} \quad (1.12)$$

Here  $\mathbf{v} = (v_1, v_2, v_3)$  - a velocity in  $X$ . The velocity (1.12) can be described with the help of tensor. It is described by the symmetric tensor

$$A = \begin{pmatrix} 0 & x_3 & x_2 \\ x_3 & 0 & x_1 \\ x_2 & x_1 & 0 \end{pmatrix}, \quad (1.13)$$

applied to velocities in  $X$ , i.e.

$$\frac{d\mathbf{R}}{dt} = A(\mathbf{v}) = \begin{pmatrix} 0 & x_3 & x_2 \\ x_3 & 0 & x_1 \\ x_2 & x_1 & 0 \end{pmatrix} \begin{pmatrix} v_1 \\ v_2 \\ v_3 \end{pmatrix} \quad (1.14)$$

When we talk about a second rank tensor we actually are talking about a surface. Therefore velocities (1.12) and (1.14) are called surfalinear or thermodynamic or wave velocities. The reason for the second and third names will become clearer later.

And what type of movement corresponds to surfalinear or simply surfacic velocity? Rotation movement in  $X$  is usually described by vector product

$$\mathbf{r} \times \mathbf{v}, \quad \mathbf{r} = (x_1, x_2, x_3), \quad \mathbf{v} = (v_1, v_2, v_3). \quad (1.15)$$

University texts usually recommend that one describe it with the help of determinant

$$\mathbf{r} \times \mathbf{v} = \begin{vmatrix} \mathbf{l} & \mathbf{m} & \mathbf{n} \\ x_1 & x_2 & x_3 \\ v_1 & v_2 & v_3 \end{vmatrix}. \quad (1.16)$$

Let us note that the texts recommend that one use polar vectors  $\mathbf{i}, \mathbf{j}, \mathbf{k}$  in (1.16) and not  $\mathbf{l}, \mathbf{m}, \mathbf{n}$ . We said above that such description was incorrect: the basis  $\mathbf{i}, \mathbf{j}, \mathbf{k}$  leaves the movement in  $X$  but actually it takes place in  $Y$ . Therefore the basis  $\mathbf{i}, \mathbf{j}, \mathbf{k}$  in (1.16) was changed to  $\mathbf{l}, \mathbf{m}, \mathbf{n}$ . But we are compelled to note that rotational movement can be described as a combination of vectors in  $\mathbf{i}, \mathbf{j}, \mathbf{k}$ , i. e. without using tensors. The trajectory (1.15) is usually

understood as movement along a circumference. The trajectory (1.16), which can be more conveniently described as the action of an antisymmetric tensor on  $\mathbf{v}$ :

$$B(\mathbf{v}) = \begin{pmatrix} 0 & -x_3 & x_2 \\ x_3 & 0 & -x_1 \\ -x_2 & x_1 & 0 \end{pmatrix} \begin{pmatrix} v_1 \\ v_2 \\ v_3 \end{pmatrix}, \quad (1.17)$$

describes rotation along the surface, i. e. along the circle swept out by the particle radius-vector. In other words purely rotational movement has in a certain sense an intermediate character between motions in spaces  $X$  and  $Y$ . But in general we are not able to describe the velocity (1.14) in terms of vectors in  $X$ .

Let us introduce the new tensor

$$C = \begin{pmatrix} 0 & x_3 & 0 \\ 0 & 0 & x_1 \\ x_2 & 0 & 0 \end{pmatrix}. \quad (1.18)$$

The velocity in  $Y$  can be described in the following way

$$\frac{d\mathbf{R}}{dt} = A(\mathbf{v}) = B(\mathbf{v}) + 2C(\mathbf{v}) \quad (1.19)$$

The symmetric tensor  $A$  is described as a sum of antisymmetric tensor  $B$  describing rotation and a certain "addition"  $2C$ . The last tensor will be called interference: it imparts the wave character to particle movement. Let us summarize everything we said above.

The following mathematical apparatus was proposed to describe Brownian and quantum-mechanical movement. In addition to the traditional 3-dimensional Euclidian space  $X$ , the 3-dimensional Euclidian space  $Y$  is appended to obtain a 6-dimensional space. Coordinate planes of the initial space  $X$  play role of the axes in the new space. Smooth trajectories in  $Y$  are "seen" from  $X$  as rotational movement with interference. Let us consider two dimensional movement to explain the last assertion. Let  $r$  and  $\varphi$  be polar coordinates on the plane. One obtains

$$x_3 = 0, \quad x_1 = r \cos \varphi, \quad x_2 = r \sin \varphi, \quad (1.20)$$

$$v_r = \frac{dr}{dt} = r', \quad v_\varphi = r \frac{d\varphi}{dt} = r\omega, \quad (1.21)$$

$$\begin{aligned} v_1 &= r' \cos \varphi - r \sin \varphi \varphi', \\ v_2 &= r' \sin \varphi + r \cos \varphi \varphi'. \end{aligned} \quad (1.22)$$

Using tensor  $A$  one obtains motion having a surfalinear velocity

$$\begin{aligned} (x_1 v_2 + x_2 v_1) \mathbf{n} &= r (v_r \sin 2\varphi + v_\varphi \cos 2\varphi) \mathbf{n} \\ &= (r r' \sin 2\varphi + r^2 \omega \cos 2\varphi) \mathbf{n} \end{aligned} \quad (1.23)$$

The axial vector  $\mathbf{n}$  is a normal to the plane  $(X_1, X_2)$ ,  $X = (X_1, X_2, X_3)$ ,  $X_i$  - are axes of the space  $X$ . Using tensor  $B$  one obtains

$$(x_1 v_2 - x_2 v_1) \mathbf{n} = r^2 \omega \mathbf{n} \quad (1.24)$$

Rotation (1.24) is similar to the second item in (1.23). But there is no uniform rotation in surfalinear motion. The multiplier  $\cos 2\varphi$  makes such rotation rather similar to pendulum movement: when  $\varphi \in [0, \pi/4)$  the particle moves decelerating into one direction, when  $\varphi \in [\pi/4, \pi/2)$  it comes back accelerating, when  $\varphi \in [\pi/2, 3\pi/2)$ , it goes on decelerating. When  $\varphi \in [3\pi/2, 2\pi)$  it returns accelerating. Then the cycle repeats. The velocity of such

movement is proportional to the area covered by the radius-vector.

The first term in (1.23) is also pendulum like because of the sine multiplier. But its value is proportional not to radius square but to the product of the radius and the velocity of this radius. Therefore it is zero when the radius is constant.

The inquisitive reader can verify that the picture is qualitatively the same in three-dimensional case but it is complicated by the additional angle is spherical system of coordinates.

Surfalinear movement kinematics introduces a new type of phenomena which explains at least some paradoxes in quantum mechanics. Surfalinear motion of a particle apparently can turn into curvilinear motion and vice versa. All the causes which lead to changing of surfalinear types of motion to trajectorian ones must be clarified in future. But here are some examples.

Light photons brush against the edges of a small screen and change their trajectorian movement to surfalinear one and lighten the center of its shadow.

We cannot understand through which of the two apertures the electron has penetrated because it changes its trajectorian movement for surfalinear one having been stricken with the whole edge and so we have lost the trajectory of its movement. But see we have redefined this high frequency electron which has forced its way through the aperture and it again moves along a trajectory.

The uncertainty principle in quantum mechanics also becomes clearer. Let us compare purely rotational and surfalinear movement of an electron  $e$ . Let  $\boldsymbol{\omega}$  be its angular velocity and  $\mathbf{r}$  its rotational radius. The electron's rotational energy is

$$E_e = e |\mathbf{r} \times (\mathbf{r} \times \boldsymbol{\omega})| = e r^2 \omega \quad (1.25)$$

The energy of its surfalinear movement

$$E_S = e R \omega. \quad (1.26)$$

And let the angular velocities of these two types of motion coincide. Thus we must compare only two values:

$$r^2 = x_1^2 + x_2^2 + x_3^2 \quad (1.27)$$

$$\text{and} \quad R = \sqrt{(x_1 x_2)^2 + (x_2 x_3)^2 + (x_1 x_3)^2} \quad (1.28)$$

One obtains squaring the two expressions:

$$\begin{aligned} r^4 &= x_1^4 + x_2^4 + x_3^4 + 2x_1^2 x_2^2 + 2x_2^2 x_3^2 + 2x_1^2 x_3^2 \geq R^2 = \\ &= x_1^2 x_2^2 + x_2^2 x_3^2 + x_1^2 x_3^2 \end{aligned}$$

For the same reasons, for any particle of mass  $m$  moving with velocity  $v$  we obtain for its trajectory's angular momentum

$$P_e = mvr = mr^2 \omega \quad (1.29)$$

and its surfalinear impulse is

$$P_S = mR\omega, \quad (1.30)$$

i.e.

$$P_e > P_S. \quad (1.31)$$

In particular for any surfalinear velocity  $T$ , such that

$$mT = \hbar \quad (1.32)$$

one obtains

$$mvr > mT = \hbar. \quad (1.33)$$

We can say that uncertainty principle is valid because surfalinear motion satisfies the principle of least action.

### 3. Mechanical Dimensions for Thermodynamic Values

Surfalinear velocity has dimension  $m^2/s$ . It reflects the fact that particle covers not a line but a surface in its movement. But do such movements exist in the nature?

Brownian particles apparently move surfalinearly. Just because of this fact, observations show that its movement time is proportional not to its path but to its path square. We daresay that quantum paradoxes are also linked with the surfalinear type of the quantum particles movement.

But doesn't the stochastic method solve the problem?

First of all, probabilistic methods are also used in a peculiar way. Not the mean, but the mean square is used to describe Brownian movement in order to take into consideration the square type dependence of the path from time.

But the main point is: "What does a probabilistic description give us?" Does it increase our understanding of the objective side of reality?

Probabilities are usually defined as frequency limits in courses for engineers. Of course, such a definition is as unsatisfactory for the mathematician as for the engineer. The mathematician hears is such definition only the fact that a sequence converges to a limit. The words about a coin and its throwing remain only as an annoying noise.

The physicist does not perceive in this the principle idea for him: "What is the physical cause for such convergence?"

Therefore in the refined mathematical courses probability is described just as a continuous in empty set normalized measure on sigma-algebra of Borel or Lebegue subsets. The only thing left for the physicist in understanding the notion of probability is his lack of comprehension of what is happening.

We can say that probabilistic description is just a confession in our incapability to understand the essence of the processes we observe.

Let us try in this section to connect the concept of surfalinear velocity with physical facts for explanation of which probabilistic approach is used. Nowadays we shall base our investigation on a system of axioms-assumptions from which theorems-conclusions will be obtained. We follow mathematical traditions here.

**Assumption 1.** The temperature  $T$  is actually just the surfalinear velocity of the particles or the thermodynamic wave.

This means that temperature has dimension  $m^2/s$ . We shall see that thermodynamic fields also have dimension  $m^2/s$ .

Let us consider the energy

$$E = kT. \quad (2.1)$$

Here  $k$  is Boltzmann's constant for a single particle. If  $T$  has dimension  $m^2/s$  then  $k$  has dimension  $kg/s$ . It was shown in paper [4], [5] that electric charge has the same dimension. It was also found in [4], [5] that mechanical value of the electric charge

$$e = 7.1 \cdot 10^{-10} \frac{kg}{s}. \quad (2.2)$$

**Assumption 2.** Boltzmann's constant is actually the electric charge, i. e.

$$k = e = 7.1 \cdot 10^{-10} \frac{kg}{s} = 1.38 \cdot 10^{-23} \frac{kg \cdot m^2}{s^2 \cdot deg}. \quad (2.3)$$

This equality enables us to find the value of one degree in mechanical terms:

$$1 \text{ deg} = 1.94 \cdot 10^{-14} \frac{m^2}{s}. \quad (2.4)$$

Thus we can interpret (2.1) energy as energy of electron's surfalinear movement.

The new understanding of temperature enables us to talk about the temperature of a single particle and not only about their ensemble as it is the case now. Thus we can talk about body temperature as related to the nearness of the surfalinear body particles' velocities and avoid the bulky construction which modern thermodynamics is compelled to use.

In the framework of the proposed approach surfalinear velocity is a vector or to be more accurate a pseudovector. Today thermodynamics understands temperature as a scalar although it talks about its spread. Therefore we shall also understand temperature as a scalar, i. e. a pseudovector's modulus. The same assertion is assumed true for electric charge and thermodynamic charge  $\hbar$ .

The question arises: is the proposed definition of temperature equivalent to the traditional one or not? Certainly not in general case. As electric charge induces electric field with dimension of trajectorian velocity  $m/s$  (details in [4]) while surfalinear movement of a particle induces thermodynamic field with  $m^2/s$  dimension.

An electric charge movement induces a wave with phase velocity. Electric charge ensemble motion with similar velocities induces a wave with group velocity.

Today the determination of temperature tells us about group velocity of the thermodynamic wave. The introduced concept of temperature of a separate particle enables us to talk about temperature as the phase velocity of the thermodynamic wave.

The field approach helps us to understand physical essence of the energy (2.1): this is the energy of the surfalinear movement of electric charges. Let us consider that this energy is linked with heat. We shall try to do this in mechanical terms.

**Assumption 3.** Thermodynamic fields exist and the thermodynamic impulse (mass and surfalinear velocity product) modulus is equal to Planck's constant  $\hbar$  which is its charge.

Planck's constant  $\hbar$  is considered to be a scalar in modern physics. In order not to create additional problems in understanding we shall also understand thermodynamic impulse as a scalar although actually Planck's constant is as electric charge a pseudovector.

Heat is a very important characteristic of the thermodynamic processes. Its connection with mechanic work is defined by the equality

$$A = a\omega, \quad (2.5)$$

Here  $\omega$  is heat and  $a$  is constant coefficient, found by experiment:

$$a = 4.188 \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2 \cdot \text{cal}}. \quad (2.6)$$

**Assumption 4.** The constant  $a$  in (2.5) is actually thermodynamic charge  $\hbar$

$$4.188 \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2 \cdot \text{cal}} = 1.05 \cdot 10^{-34} \frac{\text{kg} \cdot \text{m}^2}{\text{s}}. \quad (2.7)$$

One can obtain from this that one calorie has the dimension of angular velocity in mechanical terms

$$1 \text{ cal} = 3.99 \cdot 10^{34} \frac{\text{rad}}{\text{s}}. \quad (2.8)$$

Let us remember that one calorie is defined as heat necessary to warm 1 water gram on 1 degree. Assuming that 1 gram of water contains  $3.346 \cdot 10^{22}$  molecules one can find the angular velocity increase for one molecule:

$$A\omega = 1.2 \cdot 10^{12} \frac{\text{rad}}{\text{s}}. \quad (2.9)$$

One can rewrite the equality (2.5) as follows

$$A = \hbar\omega \quad (2.10)$$

This means that heat energy is created by a thermodynamic charges' wave behavior.

In what aspect does the introduction of mechanical dimensions help us? First of all it clarifies the concept of temperature. Today it is believed necessary to introduce separately the so called zero principle in thermodynamics: supposition about temperature existence. But the physical essence of the temperature is not explained by the zero principle. The explanation of this essence is changed by this enabling an accurate description of its measurement procedure.

Mechanical terms help us to understand temperature essence and clarify the physical cause of the ergodic theorems validity: the particles having different surfalinear movements means that they are colliding with each other. Therefore temperature "flows" from more warm to less warm parts of system. This process apparently just reflects movement of the ether particles.

We clarify the concept of temperature when we introduce the idea of surfalinear movement. Its measuring procedure can be left as it is for now. Certainly at some point a technology to measure just surfalinear velocity must arise because now we talk not only about ensemble temperature but one particle's temperature as well which we cannot measure nowadays. And this characteristic also turns to be important. We shall return to this problem soon when thermodynamic waves are considered.

If we are able to measure temperature we can postpone the problem of its physical meaning for some time having replaced the answer by its stochastic imitation.

But the problem with heat in modern physics is much more serious. When the idea of the heatbirth was rejected the heat concept turned out to be suspended. Today heat is defined with the help of temperature and this makes difficult to distinguish them. The concept of the degree is introduced into the calorie definition; thus heat turns to be just a linear function of the temperature and becomes undistinguishable with it.

When we understand energy (2.1) as electric charges movement and energy (2.10) as thermodynamic charges' wave behavior, we separate the heat and the temperature concepts and return to the ideas of Descartes and Newton, and the heatbirth concept naturally changes into the modern physics' concept of a field, and heat, temperature, and entropy become the frequency, velocity, and wave number of the thermodynamic wave. Thus we arrive at a field description of thermodynamics.

## 4. The Thermodynamic Field

We plan to introduce the concept of the thermodynamic field in the way this concept appears in electrodynamics. Therefore we shall return to the electric field idea in our discussion, and some facts from electrodynamics will be recalled as we proceed.

The concept of wave number usually is introduced for a light wave with frequency  $\nu$  moving with velocity  $c$ . The wave number is defined as the modulus of the derivative with respect to radius

$$\left| \frac{d\phi}{dr} \right| = k = \frac{\nu}{c}. \quad (3.1)$$

The problem of vector angle and angular velocity had been already mentioned above. The situation in (3.1) is analogous but the derivative is calculated with respect to  $r$  and not to time. As a result, the gradient's modulus is obtained and only later is its vector (wave vector) introduced. The equation (3.1) can be understood as the rotation angle per wave length  $\mu$ . It can be expressed in different ways:

$$\mu = \frac{2\pi}{k}, \quad (3.2)$$

$$\nu = ck. \quad (3.3)$$

Here  $\mu$  is the light wave length,  $c$  is the light velocity.

One obtains after differentiating (3.3)

$$d\nu = cdk + kdc. \quad (3.4)$$

If the light wave velocity is constant, the second item in (3.4) is zero and

$$d\nu = cdk. \quad (3.5)$$

The mechanical dimensionality introduced earlier for thermodynamic variables enable us to see that something similar is treated in thermodynamics as well.

The connection between heat and temperature is considered as quasistatic process and usually formulated in the equality:

$$\delta\omega = T_p dS, \quad (3.6)$$

Here  $\omega$  is the heat,  $T_p$  is temperature and  $S$  is entropy. The variation differential  $\delta$  is used instead of the usual differential in order to take into account that heat differential in traditional discourses is not total. Logically we must write the variation differential in (3.5) as well. But field approach helps us to avoid this problem.

Let us introduce thermodynamic wave concept as an analogue to light wave (3.3)

$$\omega = T_p S. \quad (3.7)$$

Here  $\omega$  is the heat,  $T_p$  is the temperature, i. e. the phase surfalinear velocity of the thermodynamic wave created by a separate

particle,  $S$  is the entropy, i. e. the wave number of the thermodynamic wave.

One obtains after differentiating (3.7)

$$d\omega = SdT_p + T_p dS. \quad (3.8)$$

We start from (3.8) and understand entropy as the wave number of the thermodynamic wave. Sometimes we shall use the concept of the thermodynamic wave squared, the idea analogous to light wave length

$$\lambda = \frac{\pi}{S}, \quad (3.9)$$

$$S = \frac{\pi}{\lambda}. \quad (3.10)$$

The index  $p$  belonging to the temperature (thermodynamic wave velocity)  $T$  in (3.8) underlines the fact that we are talking about the phase velocity of the wave induced by a single particle.

In electrodynamics one often considers the group velocity in addition to the phase velocity. The group velocity is induced by charges' wave behavior involving similar frequencies and correspondingly close wave numbers. The velocity of such group wave packet is defined not by equation (3.3) but by the derivative

$$\frac{dv}{dk} = g. \quad (3.11)$$

By a similar argument we can also talk, not about phase temperature  $T_p$ , but about group temperature  $T$  defined by the derivative

$$\frac{d\omega}{dS} = T. \quad (3.12)$$

It is especially important to consider this case because the concept of temperature adopted in today's physics is actually based on the idea of just such a group packet.

The phase velocity of the light wave can depend or not depend on the wave number. This depends on the medium in which the wave propagates.

In the second case (not depending), the packet velocity coincides with phase velocity. In the first case it can be as larger or smaller than the phase velocity. The same situation occurs in thermodynamics. Actually, differentiating (3.7) with respect to  $S$  one obtains in the second case

$$T = \frac{d\omega}{dS} = \frac{d(T_p S)}{dS} = T_p. \quad (3.13)$$

The group and phase velocities coincide.

One obtains in the first case

$$T = \frac{d\omega}{dS} = T_p + S \frac{dT_p}{dS}. \quad (3.14)$$

The  $T$  value depends on the sign of the second term.

Let us rewrite (3.13) and (3.14):

$$d\omega = T_p dS, \quad (3.13a)$$

$$d\omega = T_p dS + S dT_p. \quad (3.14b)$$

Equation (3.6), which is actually the entropy definition nowadays, means that temperature does not depend on the entropy. Therefore any closed path integral of the left hand and/or right

hand sides in (3.6) will be equal to zero only under the additional condition that the process is quasistatic.

And what does take place in non-static processes?

From today's point of view entropy will increase. From the thermofield point of view the second item in (3.14a) will "begin to matter".

Let us discuss this problem in greater detail.

## 5. What is Entropy?

The entropy definition (3.6) is actually based on the equality (3.13a), i. e. it uses the temperature concept as phase velocity of the thermodynamic wave. But the current accepted temperature definition demands one consider just group velocity. Experiments showing a discrepancy here led to the necessity of using the variation differential in the left hand part in (3.6). It is believed that we take into account the whole trajectory of the process and not only local characteristics by this way. The field description of the process removes this problem. Introduction of mechanic dimensions for temperature and heat enables us to throw a new look at the problem of increasing entropy.

Let us begin with the famous formula of entropy increment

$$\Delta L = k \ln \left( \frac{V_2}{V_1} \right). \quad (4.1)$$

One obtains it when analyzing free isothermal expansion of the ideal gas from volume  $V_1$  to volume  $V_2$ . Today the volume increase is interpreted as a disorder increase in the particles' situation. This chaos is described with probabilistic characteristics and often the "chaos measure"  $W$  appears instead of the  $(V_2/V_1)$  quotient.

We have assumed above that Boltzmann's constant  $k$  was actually electric charge with dimension kg/s. This means that the value  $L$  in the left hand part of (4.1) has actually the dimension of electric charge and not entropy. We can easily correct it because both are the same. One obtains dividing both sides of (4.1) by  $\hbar$ :

$$\Delta S = S_0 \ln \left( \frac{V_2}{V_1} \right), \quad (4.2)$$

here  $\Delta S = \frac{\Delta L}{\hbar}$ ,  $S_0 = \frac{k}{\hbar}$ .

The constant  $S_0$  can be interpreted as "elementary" ether (physical vacuum) entropy. It will appear once more when we come to the analysis of black body radiation. One can say that  $S$  here is the wave number for ethereal waves. It increases as logarithm of the volume contained in the surface covered by the surfalinear wave. The conclusion is: correlations (4.1) and (4.2) are consequences of the ether qualities and not of the gas itself.

In other words, the ether particles behave as molecules of an ideal gas. And a real gas's behavior is just a sum of the ideal gas movement and the movement determined by the defining qualities of the gas. Gas thermometers' observations supply us with an additional confirmation supporting this point of view. When ideal gas is used in a gas thermometer the quotient of the water boiling and freezing points  $T_s/T_i$  is equal to corresponding fraction for the pressures  $p_s/p_i$  and is equal to 1.36605 for any pressures  $p_s$  and  $p_i$ . But for the real gases this is valid only if  $p_i \rightarrow 0$ , i.

e. the real gas's particles actually disappear. And what is left? The ether remains.

Let us consider additional correlations between variables whose essences are close to entropy. I mean here heat capacity under stable pressure and stable volume.

If the entropy is  $\delta\omega/T$ , then the heat capacity under stable pressure is

$$c_p = \left( \frac{\delta\omega}{dT} \right)_p, \quad (4.3)$$

and the heat capacity under stable volume is

$$c_V = \left( \frac{\delta\omega}{dT} \right)_V. \quad (4.4)$$

The difference between them and entropy is approximately the same as between the wave number when we talk about group velocity (heat capacity) and when we talk about phase velocity (entropy). Therefore in modern theory entropy turns to be a total differential and heat capacity depends on the process (stable pressure, stable volume etc.).

A certain correlation is found for the capacities

$$c_p - c_V = k.$$

Here  $k$  is again Boltzmann's constant. And again we are compelled in order to adjust dimensionality by dividing the right hand part in (4.3) by thermodynamic charge  $\hbar$ . One obtains

$$c_p - c_V = \frac{k}{\hbar} = S_0. \quad (4.5)$$

We see that again we are talking about an ideal gas. The entropy increment, because of the volume increment in this case, is defined by equation (4.2):

$$\Delta c_V = S_0 \ln \left( \frac{V_2}{V_1} \right). \quad (4.6)$$

Now we can express a heat capacity increment when pressure is constant:

$$\Delta c_p = S_0 \left( 1 + \ln \left( \frac{V_2}{V_1} \right) \right). \quad (4.7)$$

Thus the heat capacity when pressure and volume are constant is just the ordinary entropy. The increment takes place because of a volume increase.

It becomes clear why this correlation is accurate only for ideal gases: there are more electric charges  $k$  in non-ideal gases and so ether characteristics in fluids and rigid bodies essentially differ from free ether characteristics.

And what is entropy? It is just wave number of the thermodynamic wave. Our new understanding includes the traditional one as a special case. It becomes clear that we cannot interpret entropy as the chaos measure.

## 6. The Second Principle of Thermodynamics

The equality (3.13a) asserts that to-day entropy is understood as the wave number for the phase thermodynamic velocity. In the experiments temperature is always understood as group velocity (3.14a). In other words, the assertion about entropy increas-

ing is the consequence of the second term in (3.14b) not being taken into account in modern physics.

Let us introduce the concept of the anomalous dispersion for thermodynamic wave ( $SdT < 0$ , the phase velocity is bigger than the group velocity, and entropy decreases), and the normal dispersion ( $SdT > 0$ , phase velocity is less than the group velocity, and entropy increases).

The same situation is observed in light waves. But our definition is in a certain sense analogous to the case of electric field. The normal dispersion term is used when phase velocity is bigger than the group velocity and anomalous term is used when phase velocity is less than the group velocity. Our definition was determined by the tradition when increasing entropy is considered normal because most experiments show increasing entropy.

But do opposite experiments exist? Yes, they do. Many experiments in nuclear magnetic resonance showed unexpected results. Today such states are interpreted as states with negative temperature. Let us consider these important experiments in greater detail.

In 1951 Purcell and Pound preformed experiments showing that atomic and nuclear magnetic moments which line the external magnetic field under low temperature change this line to the opposite case (see [6, 7]) when the temperature is very high. This could be explained by assuming the temperature in the entropy definition was negative. Perhaps because of this very strange concept that a domain of negative temperature begins behind infinitely big positive temperature, and it is assumed now that under negative temperature the second law of thermodynamics changes its sign: we cannot convert work into heat without compensation under negative temperature. Certainly such a construction seems strange. Observing an infinitely large temperature was certainly not ruled out by the experiment, but the effect just mentioned does take place.

In the section devoted to black body radiation it will be shown that temperature  $T_0$  equal approximately to  $10^9$  degrees exists in the thermodynamic field. This temperature plays the role of light velocity in our thermodynamics. When an isothermal process takes place with temperature higher than  $T_0$  the sign in the second principle changes and the anomalous dispersion appears. Let us try to understand the field-type cause which leads to the anomalous dispersion appearance. Let us multiply both sides of the equity (3.7) by thermodynamic charge  $\hbar$ . One obtains

$$\hbar\omega = \hbar TS. \quad (5.1)$$

The left hand side here is the heat energy which can be transferred without losses as into the energy of the surfalinear movement of the electric charges  $kT$  (2.1) as in mechanic energy. In other words, the left side of this equation under such a transformation remains constant.

The expression  $\hbar T$  in the right hand part can be considered as quite a new type of energy. This is the energy of thermodynamic charges' surfalinear movement. We shall call it thermodynamic energy. Its dimension  $\text{kg}\cdot\text{m}^4/\text{s}^2$  differs from the usual one and its coefficient  $S$  (entropy) which determines such translation changes too. The second thermodynamic law owes its existence to just this type of energy. One can also say that  $\hbar T$  is the energy of the thermodynamic wave induced by the thermodynamic

charges' movement. In order to obtain mechanic energy from it, we must previously transfer it into heat energy, the energy of thermodynamic charges' oscillations. But when in a process, the phase temperature is lower than the group temperature, then it is linked with entropy increase and consequently decreases (compensation). Just because of this, the condenser appears in the Carnot cycle. Thermodynamic energy  $\hbar T$  translates into heat energy  $\hbar\omega$  and energy losses (compensation) take place in it.

Let us consider the following cycle process similar to Carnot one.

Let us begin with the adiabatic step. In accord with definition heat changes do not take place in adiabatic processes. One obtains from field equation (3.14a):

$$d\omega = T_p dS + S dT_p = 0. \quad (5.2)$$

Heat increment is zero.

This is a differential equation with separable variables. Its solution is:

$$ST_p = S_0 T_p^0, \quad (5.3)$$

here  $S_0, T_p^0$  are initial conditions.

Thus we neither obtain additional work nor lose it because temperature increase can take place only at the cost of entropy decreasing, and vice versa.

Of course we could come to this conclusion immediately without calculations: heat can only be translated into work without loss so the total amount does not change.

This means that compensation (loss in the process of translating into work) takes place at the isothermal step.

For this step equation (3.14) looks as follows: thermodynamic wave group velocity (traditionally understood temperature)

$$T = T_p + S \frac{dT_p}{dS} = c_1 = \text{const}. \quad (5.4)$$

This is a linear differential equation. Its solution is

$$T_p = \frac{c_2}{S} + c_1 \quad (5.5)$$

or

$$S(T_p - c_1) = c_2. \quad (5.6)$$

Let us substitute temperature (5.5) into (3.14a).

$$d\omega = \frac{c_2 + c_1 S}{S} dS. \quad (5.7)$$

If  $d\omega > 0$ , then we obtain work; if  $d\omega < 0$ , we lose it; if  $d\omega = 0$ , the process is balanced. Just this last case is usually considered in the thermodynamics. (5.6) yields that we can reach equilibrium if

$$T_p = c_1. \quad (5.8)$$

And what is the temperature  $c_1$ ? This is the thermodynamic wave group velocity in the medium in which the experiment takes place. In the case of free ether this is temperature  $T_0$ . Its value will be found in the next section. In general it will be denoted as  $T_g$ . If

$$T_p > T_g, \quad (5.9)$$

entropy  $S$  must decrease, when  $T_p$  increases in order to preserve equity (5.6). If

$$T_p < T_g, \quad (5.10)$$

the entropy must increase.

If  $S$  is constant, the heat  $c_2$  can be interpreted as the heat necessary for  $T_p$  to reach  $T_g$ . The very important conclusion resulting from the Carnot cycle's consideration is the assertion that its efficiency cannot exceed unity. Let us understand this assertion from the wave point of view. Let us start from the heat

$$\omega_1 = S_1 T_1^P \quad (5.11)$$

and adiabatically translate it into  $S_2 T_2^P$  state. We cannot obtain any heat in addition, (say)

$$\omega_1 = S_2 T_2^P. \quad (5.12)$$

If  $T_2^P > T_1^P$ , then  $S_2 < S_1$ , and vice versa.

At the second step we translate the process isothermally into the state

$$\omega_2 = S_3 (T_2^P - T_g) = \omega_1 + c_2. \quad (5.13)$$

At the third step we adiabatically translate to the state with the initial temperature  $T_1$ . This takes place with entropy  $S_4$ . One obtains

$$S_3 (T_2^P - T_g) = S_4 T_1^P = \omega_1 + c_2. \quad (5.14)$$

From here

$$\frac{S_4}{S_3} = \frac{T_2^P - T_g}{T_1^P}. \quad (5.15)$$

The right hand part here is interpreted as losses in the process of going from temperature  $T_1^P$  to  $T_2^P$  and returning to  $T_1^P$ . Until  $T_2^P < T_g$  it is negative (loss). If  $T_2^P > T_g$  it is positive (gain). Physically this means that if  $T_2^P < T_g$  the thermodynamic energy is translated into work with loss (compensation). In the opposite case, it is translated into work with gain (decompensation).

We started from the heat

$$\omega_1 = S_1 T_1^P, \quad (5.16)$$

and returned to temperature  $T_1^P$  corresponding to the heat

$$\omega_1 + c_2 = S_4 T_1^P. \quad (5.17)$$

i.e.

$$S_4 - S_1 = \frac{c_2}{T_1^P}. \quad (5.18)$$

The entropies' difference decreases with the  $T_1^P$  increase. It becomes zero (the process is equilibrium) when  $T_1^P$  reaches  $T_g$ . If  $T_g$  is exceeded, this difference becomes negative (the initial entropy of the cyclic process is larger than the final one).

## 7. Absolute Black Body Radiation

The two types of energy considered above play an important role in this problem, the resolution of which concerned physicists for many decades. This is the heat energy corresponding to the thermodynamic charges' wave behavior  $\hbar\omega$  and the electric charges' surfalinear movement  $kT$ . They both appear in the Plank formula describing spectral brightness of the black body radiation.

$$I_\omega = \frac{\pi\omega^3}{8\pi^3c^2} \frac{1}{\exp\left\{\frac{\hbar\omega}{kT}\right\} - 1}. \quad (6.1)$$

Some results from the author's paper [5] will be used below. We reproduce them here. A toroidal model of electron was proposed there. It is assumed that the ether particles drawing the torus perform two movements. The rotation of the greater circumference creating the torus determines electric charge and the rotation of the smaller circumference determines thermodynamic charge  $\hbar$ .

The radius of the greater circumference

$$r_0 = 3.85 \cdot 10^{-13} \text{ m}. \quad (6.2)$$

The surface area of the circle covered by the greater torus circumference radius is

$$\pi r_0^2 = 1.48 \cdot 10^{-25} \text{ m} \cdot \pi. \quad (6.3)$$

The radius square  $r_0^2$  is designated as  $\lambda_0$  and is called thermodynamic wave squared. Thus the entropy (wave number) is defined by the equality

$$S_0 = \frac{\pi}{\lambda_0} = 2.12 \cdot 10^{25} \frac{\text{rad}}{\text{m}^2}. \quad (6.4)$$

The angular velocity of the greater circumference radius rotation in the electron torus is

$$\omega_0 = 7.8 \cdot 10^{10} \frac{\text{rad}}{\text{s}}. \quad (6.5)$$

It coincides with the Compton angular velocity for electron.

The electron's mass is taken from experiment

$$m_e = 9.1 \cdot 10^{-31} \text{ kg}, \quad (6.6)$$

and the electron's charge

$$m_e v_0 = 7.1 \cdot 10^{-10} \frac{\text{kg}}{\text{s}}. \quad (6.7)$$

We have already seen this value above.

Let us note that

$$r_0 \omega_0 = c, \quad c^2 = \lambda_0 \omega_0^2, \quad (6.8)$$

here  $c$  is light velocity in free ether. Thermodynamic charge

$$\hbar = \lambda_0 v_0 m_e = 1.05 \cdot 10^{-34} \frac{\text{kg} \cdot \text{m}^2}{\text{s}}. \quad (6.9)$$

Let us note that the less circumference radius is 2 times smaller than the greater one but its angular velocity is 2 times larger. Thus electron's spin is  $\hbar/2$ .

Taking all these facts into account in (6.1) one obtains

$$I_{\omega,S} = \frac{\omega^3}{8\pi^3\omega_0} \frac{1}{\exp\left\{\frac{S}{S_0}\right\} - 1}. \quad (6.10)$$

Here  $S = \omega/T$  is the entropy of the thermodynamic wave,  $S_0 = \omega_0/T_0$ .

The temperature  $T_0$  plays the same role in the wave thermodynamics which light velocity plays in electrodynamics.

$$T_0 = \frac{\omega_0}{S_0} = 1.84 \cdot 10^{-5} \frac{\text{m}^2}{\text{s}} = 9.5 \cdot 10^8 \text{ k deg}. \quad (6.11)$$

It is just when this value is exceeded that the changing of the sign in the second thermodynamic law occurs. Just these effects led to the idea of negative temperature which allegedly begins after infinitely big positive temperature. We said this above.

Formula (6.10) is the consequence of the thermodynamic wave (3.7) concept. It clarifies physical essence of the quotient  $\frac{\hbar\omega}{kT}$ . This is the entropy quotient in the framework of the field idea, i. e. the entropy is defined for any frequency (heat)  $\omega$  and any surfalinear velocity (temperature)  $T_p$ , due to any separate particle. In other words, phase surfalinear velocity and not group velocity, i. e. temperature as it is understood today, must figure in the Plank formula group velocity (usual temperature) can appear only as the mean after integrating  $I_\omega$  over  $\omega$ . Thus when Plank said about discrete energies that they had to be due to the separate thermodynamic charges oscillation and not the electric ones; his electrodynamic interpretation essentially hindered the understanding of his formula. Therefore it is necessary to stress that the (6.10) formula describes radiation of the thermodynamic and not electric field. And therefore it was so difficult for Plank to explain the experimental fact by electric charge oscillations. Thus he was compelled to assume discrete character of energy which is not seen in his formula. Actually the thermodynamic charges oscillate and the electric charge move with surfalinear velocity  $T_p$ . And just their ratio explains the disappearing of the ultraviolet catastrophe. And entropy unites these entire processes.

The heat  $\omega$  in (6.10) can be expressed with the help of temperature and entropy. One obtains

$$T_{S,T} = \frac{T^3 S^3}{8\pi^3 T_0 S_0} \frac{1}{\exp\left\{\frac{S}{S_0}\right\} - 1}. \quad (6.12)$$

Sometimes physicists translate from frequency formula (6.1) to the light wave length using (3.2) correlation. The above said means that such a translation is not correct. It is possible to come from the frequency-entropy form (6.10) to the temperature-square form using correlation (3.7) and (6.4). One obtains

$$T_{\lambda,T} = \frac{T^3 \lambda_0}{8\pi^3 \lambda^3 T_0} \frac{1}{\exp\left\{\frac{\lambda_0}{\lambda}\right\} - 1}. \quad (6.13)$$

But  $\lambda$  here is not the light wave length but the square of the thermodynamic wave velocity,  $T$  - radiation temperature.

It is also not correct to translate from Wien formula

$$I_{\omega,T} = \omega^3 F\left(\frac{\omega}{T}\right) \quad (6.14)$$

to light wave length dependence

$$\mu = \frac{c}{\omega}; \quad (6.15)$$

then the "extreme formula" called the Wien displacement formula

$$\mu_{\max} T = \text{const.} \quad (6.16)$$

may be obtained.

The most important problem which appeared when black body radiation was investigated is not the complete translation of the internal energy of the heated body into equilibrium radiation: the greater part of energy was conserved inside. And just this problem led to the necessity to depart from traditional mechanics.

The field point of view is not to depart from classic mechanics but to supplement it with the concept of surfalinear movement.

The internal energy of a heated body is the thermodynamic energy of the thermodynamic charges' surfalinear movement  $\hbar T$ . Its dimension is  $\text{kgm}^2/\text{s}^2$ . The translation to the usual type of energies having dimensionality  $\text{kgm}^2/\text{s}^2$  is determined by entrop

py and heat changes (6.10) or, what amounts to the same thing, by temperature and thermodynamic wave squared (6.13).

Equations (6.10) and (6.13) actually define the conditions under which translation of the thermodynamic energy into traditional one and vice-versa takes place without losses (without compensation), i. e. the process is equilibrium. Then no further exchange takes place because the process must become non-equilibrium for this. And this would contradict the first law.

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