THE SYSTEMS DYNAMICS OF THE STRUCTURED PARTICLES

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Dynamics of the structured particles consisting of potentially interacting material points is considered in the framework of classical mechanics. Equations of interaction and motion of structured particles have been derived. The expression for friction force has been obtained. It has been shown that irreversibility of dynamics of structured particles is caused by increase of their internal energy due to the energy of motion. It has been shown also that the dynamics of the structured particles is determined by two types of symmetry: the symmetry of the space and the internal symmetry of the structured particles. Possibility of theoretical substantiation of the laws of thermodynamics has been considered.

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I. INTRODUCTION

All real bodies in nature are the structured particles (SP). But the existing classical mechanics has been developed for material points (MP) or hard bodies [1] which does not exist in the nature and which have no internal structure. Therefore it is desirable to create the mechanics of SP. This mechanics will be more general than the existing mechanics of unstructured bodies. Indeed, at the MP motion in non-homogeneity space and their interaction the energy of MP motion changes only, while for the SP internal energy varies also.

As usually the change of SP internal energy is described empirically by the classical mechanics for MP. So a question arises, whether it is possible to find rigorous mathematical description of SP dynamics within the frames of the Newtonian mechanics and if possible then how? We found the answer on this question by studying the motion equation of SP when SP is an equilibrium system of potentially interacting MP.

It turns out that under certain conditions dynamics of such systems is irreversible [2-4]. These conditions are formulated as follows:

1). The energy of an SP must be presented as a sum of internal energy and the energy of SP motion as a whole.
2). Each material point in the system must be connected with a certain SP independent of its motion in space.
3). During all the process the subsystems are considered to be equilibrium.

The first condition is necessary to introduce internal energy in the description of system dynamics as a new key parameter charactering energy variations of SP. The second condition enables not to redefine SP after mixing of MP. The last condition is taken from thermodynamics. It is equivalent to the condition of weak interactions in the SP, which do not violate SP equilibrium. Moreover, it implies that each SP contains so many elements that it can be described using the concept of equilibrium system.

In this paper we consider derivation of the motion equation of interacting SP. With the help of this equation it is shown how the mechanism of friction can be explained in the frame of laws of the classical mechanics. It is shown also how based on the hypothesis of local equilibrium, which enables to represent non-equilibrium systems as an ensemble of equilibrium subsystems, one can generalize the obtained results for two interacting SP. It is also shown how Lagrange, Hamilton and Liouville equations for non-equilibrium systems are derived from the equation of motion of a set of equilibrium SP. We consider how such equations are different from their canonic prototypes for the system of MP. We consider why the SP dynamics is determined by the two types of symmetries: the symmetry of space in which the SP motion and internal symmetry of distributions of elements of SP. It is shown how the main equation of thermodynamics can be derived from the equation of SP interaction and how the concept of entropy arises in classical mechanics.

II. THE MOTION EQUATION OF EQUILIBRIUM STRUCTURAL PARTICLES

It was shown in [4] that for obtaining of the SP motion equation it is necessary to define the energy of each SP as a sum of internal energy and energy of its motion. Differentiating energy of system with respect to time and using a condition of its conservation, the equation for an energy exchange between SP can be obtained and then with its help the equation of motion of SP can be found. After that the equation of motion for SP can be obtained in two stages. At the first stage, based on the condition of energy conservation, we obtain the equation of motion for the system in the field of external forces. Then we take a system consisting of SP and obtain their equations of motion when the external field for one SP is the field of forces of the other SP. Forces acting between the SP can be obtained from MP potential interaction.
Let us show how the equation of motion for a system of \( N \) material points with weights \( m = 1 \) can be obtained [2-4]. Forces acting between pairs of \( MP \) are assumed to be central and potential. The energy of the system \( E \) is equal to the sum of kinetic energies of \( MP \). Thus \( T_N = \sum_{i=1}^N m v_i^2/2 \), their potential energy in the field of external forces, \( U_{N}^{env} \), and potential energy of their interaction \( U_N(r_{ij}) = \sum_{i=1}^N \sum_{j=i+1}^N U_{ij}(r_{ij}) \), where \( r_{ij} = r_i - r_j \), \( r_i, v_i \) are coordinates and velocities of the \( i \)-th \( MP \). Thus, \( E = E_N + U_{N}^{env} = T_N + U_{N}^{env} = const. \)

By substituting variables we represent the energy of the system as a sum of the motion energy of the center of mass (CM) and the internal energy. Differentiating this energy with respect to time, we will obtain [3]:

\[
V_N M_N \dot{V}_N + \dot{E}_N^{ins} = -V_N F_{env}^{ins} - \Phi_{env}^{ins} \tag{1}
\]

Here \( F_{env}^{ins} = \sum_{i=1}^N F_i^{env}(R_N, \tilde{r}_i), \dot{E}_N^{ins} = \dot{T}_N^{ins}(\tilde{v}_i) + \dot{\Phi}_N^{ins}(\tilde{v}_i) = \sum_{i=1}^N v_i (m \ddot{v}_i + F(\tilde{r}_i)), \Phi_{env}^{ins} = \sum_{i=1}^N v_i F_i^{env}(R_N, \tilde{r}_i), \)

\[
\frac{\dot{\tilde{r}}_i}{v_i} = R_N + \tilde{r}_i, M_N = mN, v_i = \tilde{V}_N + \tilde{v}_i, F_i^{env} = \frac{\partial U_{env}^{ins}/\partial \tilde{r}_i}, \tilde{v}_i, \tilde{r}_i \text{ are the coordinates and velocity of } i \text{-th } MP \text{ in the } CM \text{ system, } R_N, V_N \text{ are the coordinates and velocity of the } CM \text{ system.}
\]

The equation (1) represents the balance of the energy of the system, \( MP \) in the field of external forces.

The first term in the left-hand side of the equation determines the change of kinetic energy of the system. The second term determines the change of internal energy of the system, \( \dot{E}_N^{ins} \). This energy depends on coordinates and velocities of \( MP \) relative to the \( CM \) of the system.

The right-hand side corresponds to the work of internal forces changing the energy of the system. The first term changes \( \dot{E}_N^{ins} = V_N M_N \dot{V}_N \). The second term determines the work of \( F_{env}^{ins} \).

Let us determine the condition when the work of non-potential forces is not equal to zero. We must take into account that \( F_{env}^{ins} = F_{env}^{ins}(R \tilde{r}_i) \) where \( R \) is the distance from the source of force to the \( CM \) of the system. Let us assume that \( R >> \tilde{r}_i \). In case the force \( F_{env}^{ins} \) can be expanded with respect to a small parameter. Leaving in the expansion terms of zero and first order we can write:

\[
F_i^{env} = F_i^{env}(R + \langle \nabla F_i^{env} \rangle|R \tilde{r}_i) \]

Taking into account that

\[
\sum_{i=1}^N \tilde{v}_i = \sum_{i=1}^N \tilde{r}_i = 0 \quad \text{and} \quad \sum_{i=1}^N F_i^{env}(R) = NF_i^{env}(R) = F_0^{env},
\]

we get from (1):

\[
V_N (M_N \dot{V}_N) + \sum_{i=1}^N \bar{m} \tilde{v}_i (\tilde{v}_i + F(\tilde{r}_i)) \approx -V_N F_0^{env} - \langle \nabla F_0^{env} \rangle R \sum_{i=1}^N \tilde{v}_i \tilde{r}_i \tag{2}
\]

In the right-hand side of equation (2) the force \( F_0^{env} \) in the first term depends on \( R \). It is a potential force. The second term depending on coordinates of \( MP \) and their velocities relative to the \( CM \) of the system determines changes in the internal energy of the system. It is proportional to the divergence of the external force. Therefore, in spite of the condition \( R >> \tilde{r}_i \), the values of \( \tilde{v}_i \) may be not small, and the second term cannot be omitted. Forces corresponding to this term are not potential forces. So, the change in the internal energy will be not equal to zero only if the characteristic scale of inhomogeneities of the external field is commensurable with the system scale.

Thus, inhomogeneity of space leads to the inhomogeneity of time for the system. It is connected with possibility of increase in internal energy of system at the expense of energy of its motion and impossibility of returning of the system’s internal energy into the energy of its motion due to the law of momentum conservation. But the law of preservation of full energy is carried out.

Equation (2) confirms assumption of A. Poincare [5] that it is necessary to take into account structures of interacting bodies at rather small distances between them.

Dynamics of an individual \( MP \) as well as dynamics of a system of \( MP \) can be derived from equation (1). A \( MP \) does not have an internal energy, and forces acting on it are caused by potential forces of interaction with other \( MP \) and the external force. Therefore the motion of a \( MP \) is determined by the work of potential forces transforming the energy of the external field into its kinetic energy only.

Unlike \( MP \), a system has its internal energy. Therefore the work of external forces over the system causes changes in its \( T_N^{tr} \) and \( E_N^{ins} \), i.e. the external force breaks up into two components. The first component is a potential force. It changes momentum of the system’s \( CM \). The second component is non-potential. Its work changes \( E_N^{ins} \). Hence, the motion of the system is determined by the work of potential and non-potential forces transforming the external field energy into the energy of \( CM \) motion and internal energy.

Multiplying eq.(1) by \( V_N \) and dividing by \( V_N^2 \) we find the equation of a system motion [4]:

\[
M_N \ddot{V}_N = -F_{env}^{ins} - \alpha_N V_N \tag{3}
\]

where \( \alpha_N = [E_N^{ins} + \Phi_{env}^{ins}]/V_N^2 \) is a coefficient determined by the change of internal energy.

The equation (3) is a motion equation for \( SP \). The first term in the right-hand side of the equation determines the system acceleration, and the second term determines the change of its internal energy. The eq. (3) is reduced to the Newton equation if it is possible to neglect variation in the internal energy.

Thus, the system state in the external field is determined by two parameters: the energy of motion and the internal energy. Each type of energy has its own force. The change in the motion energy is caused by the potential component of the force, whereas the change in
the internal energy is caused by the non-potential component.

Let us show how to obtain the equation for interaction two equilibrium systems \(SP\). For this purpose we take the system consisting of two \(ES\) and \(K\). The \(L\) is the number of elements in the \(LSP\) and \(K\) is the number of elements in \(KSP\), i.e., \(L + K = N\). Let \(LV_L + KVK = 0\), where \(V_L\) and \(V_K\) are velocities of \(L\) and \(K\) equilibrium subsystems relative to the \(CM\) of the system. Differentiating the energy of the system with respect to time, we obtain: 
\[
\sum_{i=1}^{N} v_i \dot{v}_i + \sum_{j=i+1}^{N} v_j F_{ij} = 0,
\]
where \(F_{ij} = U_{ij} = \partial U / \partial v_{ij}\).

In order to derive the equation for \(LSP\), in the left-hand side of the equation we leave only terms determining change of kinetic and potential energy of interaction of \(LSP\) elements among themselves. All other terms we displace into the right-hand side of the equation and combine the groups of terms in such a way that each group contains the terms with identical velocities. In accordance with Newton equation, the groups which contain terms with velocities of the elements from \(KSP\) are equal to zero. As a result the right-hand side of the equation will contain only the terms which determine the interaction of the elements \(LSP\) with the elements \(KSP\). Thus we will have:
\[
\sum_{i=1}^{L} v_{iL} \dot{v}_{iL} + \sum_{j=1}^{K} \sum_{j=1}^{K} F_{iLjK} v_{iLjK} = \sum_{i=1}^{L} \sum_{j=1}^{L} F_{iLjK} v_{iLjK}
\]
where double indexes are introduced to denote that a particle belongs to the corresponding system. If we make substitution \(v_{iL} = \dot{\tilde{v}}_{iL} + V_L\), where \(\tilde{v}_{iL}\) is the velocity of \(iL\) particle relative to the \(CM\) of \(L\) -SP, we obtain the equation for \(LSP\). The equation for \(KSP\) can be obtained in the same way. The equations for two interacting systems can be written as [4]:
\[
V_L M_L \dot{V}_L + \dot{E}^{ins}_{L} = -\Phi_L - V_L \Psi \tag{4}
\]
\[
V_K M_K \dot{V}_K + \dot{E}^{ins}_{K} = \Phi_K + V_K \Psi \tag{5}
\]

Here \(M_L = mL, M_K = mK, \Psi = \sum_{i=1}^{L} F_{iL}^K; \Phi_L = \sum_{i=1}^{L} \tilde{v}_{iL} F_{iL}^K, \Phi_K = \sum_{j=1}^{K} \tilde{v}_{jK} F_{jK}^L, F_{iL}^L = \sum_{j=1}^{K} F_{iLjK}; F_{jK}^L = \sum_{i=1}^{L} F_{iLjK}; \dot{E}^{ins}_{L} = \sum_{i=1}^{L} \sum_{j=1}^{L} v_{iLjK} \left(\frac{mv_{iLjK}}{L}\right) + F_{iLjK}; \dot{E}^{ins}_{K} = \sum_{j=1}^{K} \sum_{j=1}^{K} v_{iKjL} \left(\frac{mv_{iKjL}}{K}\right) + F_{iLjK} \right\}.

The equations (4, 5) are equations for interactions two \(SP\). They describe energy exchange between \(SP\). Independent variables are macro-parameters and micro-parameters. Macro-parameters are coordinates and velocities of the motion of \(CM\) of \(SP\). Micro-parameters are relative coordinates and velocities of \(MP\).

Therefore the equation of \(SP\) interaction binds together two types of description: on the macrolevel and on the microlevel. The description on the macrolevel determines dynamics of an \(SP\) as a whole and description on the microlevel determines dynamics of the elements of an \(SP\).

The potential force, \(\Psi\), determines the motion of an \(SP\) as a whole. This force is the sum of potential forces acting on the elements of one \(SP\) from the other \(SP\).

The forces determined by terms \(\Phi_L\) and \(\Phi_K\) transform the motion energy of \(SP\) into their internal energy as a result of chaotic motion of elements of one \(SP\) in the field of forces of the other \(SP\). As in the case of the system in the external field, these terms are not zero only if the characteristic scale of inhomogeneity of forces of one system is commensurable with the scale of the other system. The work of such forces causes violation of time symmetry for \(SP\) dynamics.

The equations for \(SP\) motion corresponding to the equations (4,5) can be written as [4]:
\[
M_L \dot{V}_L = -\Psi - \alpha_L V_L \tag{6}
\]
\[
M_K \dot{V}_K = \Psi + \alpha_K V_K \tag{7}
\]
where \(\alpha_L = (\dot{E}^{ins}_L + \Phi_L)/V_L^2, \alpha_K = (\Phi_K - \dot{E}^{ins}_K)/V_K^2\).

The equations (6, 7) are motion equations for interacting \(SP\). The second terms in the right-hand side of the equations determine the forces changing the internal energy of the \(SP\). These forces are equivalent to the friction forces. Their work is a sum of works of forces acting on the \(MP\) of one \(SP\) from the other \(SP\).

The coefficients \(\alpha_L, \alpha_K\) determine efficiency of transformation of the energy of \(SP\) motion into their internal energy. These coefficients are friction coefficients. Therefore equations (6, 7) enable to determine analytical form of non-potential forces in the non-equilibrium system causing changes in the internal energy of the \(SP\).

III. THE GENERALS OF LAGRANGE, HAMILTON AND LIOUVILLE EQUATIONS FOR EQUILIBRIUM SYSTEMS

Let us show qualitative difference of Lagrange, Hamilton and Liouville equations for the systems of \(MP\) from similar equations for \(SP\).

Using Newton equation one can derive Hamilton principle for \(MP\) from differential D’Alambert principle [6]. For this purpose the time integral of virtual work done by effective forces is equated to zero. Integration over time is carried out provided that external forces possess a power function. It means that the canonical principle of Hamilton is valid only for cases when \(\sum F_i \delta R_i = -\delta U\), where \(i\) is a particle number, and \(F_i\) is a force acting on this particle. But for interacting \(SP\) the condition of conservation of forces is not fulfilled because of the presence of
a non-potential component. Therefore Hamiltonian principle for SP as well as Lagrange, Hamilton and Liouville equations must be derived using eq. (3).

Liouville equation for non-equilibrium system consisting from a set of equilibrium SP is written as [2, 4]:

\[
df/dt = - \sum_{L=1}^{R} \partial F_L / \partial V_L
\] (8)

Here \( f \) is a distribution function for a set of \( SP \), \( F_L \) is a non-potential part of collective forces acting on the \( SP \), \( V_L \) is the velocity of \( L-SP \).

The right-hand side of the equation is determined by the efficiency of transformation of the \( SP \) motion energy into their internal energy. For non-equilibrium systems the right-hand side is not equal to zero because of non-potentiality of forces changing the internal energy.

The state of the system as a set of \( SP \) can be defined in the phase space which consists of \( 6R - 1 \) coordinates and momentums of \( SP \), where \( R \) is the number of \( SP \). Location of each \( SP \) is given by three coordinates and \( 1 \) momentums; \( 2 \) coordinates \( x \) and \( y \), \( - \) momentum \( \dot{x} \), \( x \) - coordinate \( \dot{y} \), \( y \) - coordinate. The configuration space is interval displaying infinitesimal distance between two points of configuration space; \( \tilde{s} = \sqrt{m_i x_i} \), \( \dot{x} = \sqrt{m_i y_i} \), \( \tilde{z} = \sqrt{m_i z_i} \) are coordinates of the \( i \) element; \( m_i \) is a mass of the \( i \) -element. The configuration space is \( 3N \) dimensional Euclidian spaces for \( N MP \). In general case the linear element will be set in the square-law differential form of corresponding variables:

\[
\ddot{s}^2 = \sum_{i,k=1}^{n} g_{ik} d\tilde{x}_i d\tilde{x}_k
\] (10)

where \( g_{ik} = g_{ki} \) is symmetrical metrics tensor, \( n = 3N \).

If we have \( p \) kinematics restrictions \( f_i = f_i(x_1, x_2 ... x_n) \), \( i = 1, 2 ... p \), the motion of the system will be in \( t = 3N - p \) dimensional hyperspace. In this case we have:

\[
\ddot{s}^2 = \sum_{i,k=1}^{n} a_{ik} dq_i dq_k
\]

where \( a_{ik} \) is known function in a new coordinates. If as kinematics conditions are potential forces then the equation (8) will be equivalent to the motion equation of \( MP \). But for system which is a set of \( SP \), the energy part is distributed by non-potential forces. There is a question what will be an interval in this case?

Let’s show, that for answer on this question it is necessary to present energy of system in the form of two parts: energy of motion of the center of mass of \( SP-T_N^v \), and internal energy of \( SP-T_N^{ins} \). I.e. the interval corresponding for system \( SP \) also should consist of two parts. In this case the \( T_N^v \), \( T_N^{ins} \) expressions (7) can be written down as:

\[
\dot{s}^2 = (2T_N^v + 2T_N^{ins}) dt^2 = ds^2_{tr} + ds^2_{ins} = N\dot{V}_0^2 dt^2 + \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \dot{v}_{ij}^2 dt^2 / N
\] (11)

where \( \dot{V}_0 = \sum_{i=1}^{N} \dot{v}_i/N \), \( \dot{v}_{ij} = \dot{v}_i - \dot{v}_j \).

Let us transform the energy \( T_N \) by replacement: \( \dot{v}_i = \dot{V}_0 - \bar{v}_i \), where \( \sum_{i=1}^{N} \dot{v}_i = N\dot{V}_0 \), i.e. \( \sum_{i=1}^{N} \bar{v}_i = 0 \). Then we will have:

\[
T_N = N\dot{V}_0^2 / 2 + \dot{V}_0 \sum_{i=1}^{N} \dot{v}_i + \sum_{i=1}^{N} \bar{v}_i^2 / 2
\] (12)

Because \( \sum_{i=1}^{N} \bar{v}_i = 0 \), then we have

\[
\sum_{i=1}^{N} \bar{v}_i^2 / 2 = 1/(2N) \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \dot{v}_{ij}^2
\] (13)

As a result we obtain:

\[
\dot{s}^2 = (2T_N^\text{tr} + 2T_N^\text{ins}) dt^2 = ds^2_{\text{tr}} + ds^2_{\text{ins}} = N\dot{V}_0^2 dt^2 + \sum_{i=1}^{N} \bar{v}_i^2 dt^2
\] (14)

Thus, the square of an interval of non-equilibrium system breaks up to the sum of squares of two intervals.
The first corresponds to the motion energy of \( SP \) center of mass and the second corresponds to the internal energy of system. It is follows from here that the interval of the non-equilibrium system which consists of a set of \( SP \) breaks up to two independent intervals characterizing dynamics of system: \[ ds_{tr}^2 = NV_0^2 dt^2 \] and \[ ds_{ins}^2 = \sum_{i=1}^{N} c_i^2 dt^2. \] These intervals are orthogonally and they correspond to adjacent of a triangle for a full interval of system in configuration space.

The change of the \( SP \) center of mass motion energy is caused by work of potential forces \( F_{tr} \). Their work is defined by expression: \[ A_{tr} = \int F_{tr} d\mathbf{r}, \] \[ F_{tr} = \nabla \varphi, \] where \( \varphi \) is scalar function, \( d\mathbf{r} \) is a distance of systems motion.

The forces \( F_{ins} \) which change of the internal energy \( SP \) are non-potential. Their work consists from the work on change of \( MP \) motion energy relative to the center of mass, i.e. \[ A_{ins} = \sum_{i=1}^{N} \int F_i dr_i, \] where \( dr_i \) -moving of \( i \)-th element of system relative to the center of mass. And because \[ \sum_{i=1}^{N} F_i = 0 \] then \[ \int \sum_{i=1}^{N} F_i d\mathbf{r} = 0 \] for any possible way of moving of system. I.e. the potential component of the external force \( F_{tr} \) acting on \( SP \) changes \( s_{tr} \) but does not change \( s_{ins} \). The work of non-potential forces, \( F_{ins} \) changes \( s_{ins} \) but does not change \( s_{tr} \). The variables defining motion of the center of mass are macroparameters, and the variables defining change of internal energy are microparameters.

Thus for the description of dynamics of the non-equilibrium system it is necessary to present this system as a set of \( SP \) and then it is necessary to represent \( SP \)'s energy in the form of the sum of two types of energy: internal energy and energy of \( SP \) motion. In the nature we deal with the real bodies possessing internal energy. At their interaction the part of energy go to their heating. This energy transforming is realized by the friction force. So the \( SP \) dynamics is determined by the two types of symmetries: the symmetry of space in which the \( SP \) motion and internal symmetry of distributions of elements of \( SP \). Thus the necessity of splitting of the energy on two parts has under itself a real basis.

V. THE EQUATIONS OF INTERACTION OF SYSTEMS AND THERMODYNAMICS

Equations (1-8) give relationship between mechanics and thermodynamics [4, 8]. According to the basic equation of thermodynamics the work of external forces acting on the system splits into two parts. The first part corresponds to reversible work. In our case it corresponds to the change of the motion energy of the system as a whole. The second part of energy goes on heating. It corresponds to the internal energy of the system.

Let us take a motionless non-equilibrium system consisting of \( R \) equilibrium subsystems. Each equilibrium subsystem consists of a great number of elements \( N_L \gg 1 \), where \( L = 1, 2, 3...R \), \( N = \sum_{L=1}^{R} N_L \). Let \( dE \) be work done over the system. In thermodynamics energy \( E \) is called internal energy (in our case it is equal to the sum of all energies of equilibrium subsystems). It is known from thermodynamics that \( dE = dQ - P dY \) [8]. Here, according to generally accepted terminology, \( E \) is the energy of the system; \( Q \) is the thermal energy; \( P \) is the pressure; \( Y \) is the volume. The equation of interaction between \( SP \) is also a differential of two types of energy. It means that \( dE \) in the \( SP \) is redistributed in such a way that some part of it changes energy of relative motion of the \( SP \) and the other part changes the internal energy. Thus, it follows that entropy may be introduced into classical thermodynamics if it is considered as a quantity characterizing increase in the internal energy of an \( SP \) at the expense of energy of their motion. Then the increase in entropy can be written as [3, 4]:

\[
\Delta S = \sum_{L=1}^{R} \{ N_L \int \sum_{k=1}^{N_L} F^L_{k} v_k / E^L | dt \} \tag{15}
\]

Here \( E^L \) is the kinetic energy of \( L-SP \); \( N_L \) is the number of elements in \( L-SP \); \( L = 1, 2, 3...R \); \( R \) is the number of \( SP \); \( s \) is the number of external elements which interact with \( k \) element belonging to the \( L-SP \); \( F^L_{k} \) is the force acting on the \( k \)-element; \( v_k \) is the velocity of the \( k \)-element.

Based on the generally accepted definition of entropy we can derive expression for its production and define necessary conditions for stationarity of a nonequilibrium system [4].

VI. CONCLUSION

The classical mechanics collides with insuperable difficulties in attempt to describe evolution of non-equilibrium systems. The main reason is that the process of evolution is irreversible but the classical mechanics is reversible [9, 10]. The reversibility of classical mechanics is defined by the nature of the second law of Newton. According to this law the acceleration of unstructured bodies is proportional to the force acting on it. Therefore the region of application of the second law of Newton is restricted by unstructured bodies. It means that the second law of Newton is inapplicable for the description of dynamics of the real bodies possessing a friction. Hence for removal of the mentioned restrictions of classical mechanics it is necessary to define friction forces rigorously on the basis of Newton’s second law.

The analysis of dynamics of a hard-discs system has led to the conclusion that in order to solve this problem it is necessary to find the motion equation of \( SP \). It has been done for a case when \( SP \) represents a system of potentially interacting \( MP \), moving in the field of external forces.

During the process of search of a way which could lead to the \( SP \) motions equation and then as a result of its analysis, the following conclusions were found out.
The motion and evolution of the system are defined by two types of symmetry: the symmetry of space in which it is moving and its internal symmetry. In accordance with these two types of symmetries the energy of system also breaks up on to two types: the motion energy of system and its internal energy. In its turn, the change of these types of energy is also defined by two types of forces. Transformation of energy of \( SP \) motion is caused by potential force. Transformation of internal energy \( SP \) is caused by work of non-potential force. The work of the non-potential force leads to irreversibility of \( SP \) dynamics.

The non-equilibrium systems in approach of the local equilibrium can be presented as a set of the equilibrium subsystems which are in motion relative to each other. In this case the description of dynamics of system by means of the \( SP \) motion equation can be carried out. The state of the system as a set of \( SP \) can be defined in the phase space which consists of \( 6R-1 \) coordinates and momentums of \( SP \), where \( R \) is the number of \( SP \). Location of each \( SP \) is given by three coordinates and their momentums. The phase space which is determined by coordinates and velocities of \( SP \) is compressible.

The dynamics of the non-equilibrium system composed of a set of \( SP \) is determined by the Liouville equation for equilibrium \( SP \). These systems acquires an equilibrium state when all energy of \( SP \) motion transforms into its internal energy.

The offered expansion of classical mechanics and the deterministic explanation of irreversibility open a way to the substantiation of thermodynamics. According to the motion equation for \( SP \) the first law of thermodynamics follows from the fact that the work of external forces changes both the energy of particle’s motion and their internal energy. The second law of thermodynamics follows from irreversible transformation of energy of relative motion of system’s particles into their internal energy.

The motion equation for \( SP \) also states impossibility of existence of structureless particles in classical mechanics, which is equivalent to infinite divisibility of matter.

Thus, the replacement of model of system in the form of set \( MP \) on a model in the form of a set of \( SP \) leads to essential expansion of classical mechanics. Such expansion allows, remaining within the frame of laws of Newton’s mechanics, to offer the deterministic explanation of irreversibility and, thereby, to enter the concept of entropy and evolution into the classical mechanics. It is a bright example of that the further development of physics is impossible without perfection of models on which basis it has been constructed.

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