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ENERGODYNAMICS

THERMODYNAMIC FUNDAMENTALS OF SYNERGETICS

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The monograph generalizes the methods of non-equilibrium thermodynamics underlying synergetics to the processes of useful conversion of energy in any forms, irrespectively of the level of the universe they touch upon, the media they occur in and the field of knowledge they belong to. The theory called for short "energodynamics" features an interdisciplinary character, a system approach to objects of investigation, the exclusion of hypotheses and postulates from the theory grounds, the non-idealization of processes and systems beyond the uniqueness conditions imposed and the rate, productivity, irreversibility and counterdirectivity of processes in spatially heterogeneous media as explicitly allowed for in the basic equations of energodynamics.

The book concentrates most attention on the synthesis of the basics of fundamental disciplines and on the deductive substantiation of fundamental principles, laws and equations for equilibrium and non-equilibrium thermodynamics, classic and quantum mechanics, the theory of heat- and mass-exchange, hydrodynamics and electrodynamics.

A considerable attention is also paid to the development and experimental verification of a number of new applications the theory provides, as well as to the analysis and elimination of the paralogisms discovered from the positions of energodynamics in the majority of fundamental disciplines.

The book is intended for the audience understanding the necessity of updating the conceptual base of modern natural science and being interested in the prospects of alternative energetics, the phenomena at the interfaces between various sciences, the problems of self-organization and global evolution. It may be useful also for the researches, university teachers and students keen-set for the system vision of the world, the knowledge integration and interdisciplinary schooling.

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(St.-Petersburg, "Science", 2008),
awarded Leibniz's medal of the European
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INTRODUCTION

"However inevitable is a critique of the classic theories, it does not mean at all a detraction from the excellent achievements of masters of science, whose intuition has led us forth on the right way – it is just necessary to sweep aside the rubbish, which our too humble conventionalism did not dare to remove".

Max Born

To solve the problems arising at the interfaces between fundamental sciences, a theory is needed making it possible to uniformly describe physical, chemical, biological, astrophysical and the like properties and motions of the material world. The greatest scientific achievements of the past were benchmarks on the way to this aim. These may include the integration of terrestrial mechanics with celestial one made by J. Newton in the XVII century, optics with the theory of electricity and magnetism by D.C. Maxwell in the XIX century, chemistry with atomic physics within quantum mechanics of the XX century. A noticeable milestone on this way has become known as creating the theory of elementary particles and forces known as the Standard Model, as well as the integration of electromagnetism and weak interactions concepts.

However, attempts to create a theory unified for all interactions are being accompanied by increscent negative tendencies in the development of fundamental sciences. The spectrum of basic disciplines and the covered spheres of natural science being extended, the tendency becomes ever more apparent to avoid by all means a regular revision of scientific fundamentals since that would deprive the investigators of their fulcrum so desirable. This explains the attempts to cram new empirical facts into "Procrustean bed" of the obsolete notional system with the help of various hypotheses and postulates and the extremely morbid treatment by specialists of any attempts (including constructive ones) to modify something in the foundation of these theories. Therefore only a few of investigators dare such attempts, as a rule. The author of this book is among them. In a number of his books (Thermodynamics of Non-Equilibrium Processes…, 1991; Fundamental Energodynamics, 1992; Thermokinetics, 1999; Energodynamics, 2008), the author, by the concrete examples, made an attempt to improve the situation. This is the objective of the monograph "Energodynamics" in its English edition, too, dedicated to the results of the author's investigations for last years.

It is known that the main content of theoretical physics as a foundation of modern natural science can be obtained based on the postulates of space and time homogeneity and isotropism (E. Noether, 1918; L. Landau, E. Livshits, 1940…2004). However, when constructing a nonhypothetical and postulate-free theory, which is energodynamics as the author sees it, such an approach can not be assumed as its basis. Therefore we will rely here on exclusively those statements that do not need an additional experimental verification.

As the prototype of energodynamics classic thermodynamics may serve, which is, by A. Einstein, an "only general physics theory, about which I am sure that within the applicability of its main concepts it will never be overthown (for hardened sceptics' special notice)". The main advantage of thermodynamics has always been the possibility to obtain a great number of consequences from various phenomena based on a small number of primary principles (basics), no necessity in model representation for matter microstructure and molecular behavior of phenomena, and, ultimately, the indisputable validity of its consequences. For these merits classic thermodynamics has long been called the "queen of sciences". As M. Planck rightly noted, "this is a remarkable scientific system, which details are inferior to the whole System neither in beauty nor in bright perfection". The power of the thermodynamic (phenomenological in its base) method is well-known. That showed up once again in the XX century in creating thermochemistry (W. Nernst, 1929; et al.), biophysics (A. Patton, 1964; et al), the phenomenological theory of superfluidity (L. Landau, 1941), superconductivity (L. Landau, V. Ginzburg, 1950) and the theory of irreversible processes (L. Onsager, 1933; I. Prigogine, 1960; et al). As I. Prigogine stressed in his Nobel prize winner's lecture (1978), the thermodynamic conceptions are called upon to play ever growing role in modern natural science.

The objective of this book is to generalize the methods pertaining to thermodynamics of irreversible processes and to create on this basis *energodynamics*[1] – a fundamental discipline studying the general laws covering nonstatic (running with finite rate) processes of energy transfer and conversion in any forms regardless of the field of knowledge they be-

[1] The term "energodynamics" first proposed by A. Veinik (1968) pinpoints that this dynamics means not only the thermal form of motion.

long to. The major task therein was to keep untouched the basic advantage of the classic thermodynamic method – indisputable validity of its consequences so that energodynamics could serve as the "touchstone" for any of the natural science disciplines.

The book offered for the reader consists of six parts. Part 1 – From Thermodynamics to Energodynamics (Chapters 1 and 2) – describes the methodological features of energodynamics as a theory generalizing the methods of equilibrium and nonequilibrium thermodynamics to nonthermal forms of energy and nonthermal engines. Such an approach dictates the necessity to construct energodynamics on at most general notional and conceptual base not alien to such notions as time, rate and productivity of real processes. These tasks are associated with the spatially heterogeneous systems considered as a single whole, the system approach to object of investigations, the exclusion of hypotheses and postulates from theoretical grounds, the non-idealization of processes and systems beyond the uniqueness conditions applicability, the adequacy principle observed at system state description and the explicit consideration for opposite direction of processes running in different parts of such systems. The implementation of these principles requred introducing the specific parameters of spatial heterogeneity for systems under investigation. These parameters considerably extended the potentials of the thermodynamic method based on the properties describing the exact differential of functions of such variables. They allowed bringing the energy back to its simple and clear primordial sense as the system capability for work, separating its ordered part and finding the characteristic functions of nonequilibrium state, which provide not only quantitative, but also qualitative characteristic for various forms of energy in terms of their capability to do work . On this basis a body of mathematics pertaining to energodynamics has been successfully elaborated as suitable for studying real processes with any irreversibility degree. The characteristic feature of this body of mathematics is the fact that it is entirely based on the math properties of the characterictic functions mentioned and involves the particular data on the properties of systems under investigation at only final stage of investigation and only as uniqueness conditions of a kind. This allows keeping untouched the basic advantage of the thermodynamic method – indisputable validity of its consequences within the applicability of the said uniqueness conditions. Further application of this method to various scientific disciplines has confirmed its heuristic value.

Part 2 – Fundamental Disciplines as Consequences of Energodynamics (Chapters 3–9) – starts from describing nontrivial consequences of energodynamics obtained in almost all sheres of its application. This section provides a consistently deductive substantiation of major principles, laws and equations of a number of fundamental disciplines (classic and quantum mechanics, equilibrium and nonequilibrium thermodynamics, the heat and mass exchange theory, hydro- and aerodynamics, electrostatics and electrodynamics, the theory of thermal and nonthermal engines, the self-organization and evolution theory) as consequences from energodynamics. Such consequences include the thermodynamic derivation of Newton laws of gravitation and Maxwell equations, principle of least constraint and Schrödinger stationary equations, which were considered nonderivable from whatever primary principles.

In addition to that a number of new results have been obtained within the said disciplines. In mechanics those were the improvement of a number of initial notions and further generalization of all Newton laws. In quantum mechanics major consequences from this theory on strictly deterministic base have been successfully obtained on this way (Planck radiation law, photoeffect law and spectral lines expressions). It appeared to be possible to supplement the quantum theory with the electron orbit parameters definition.

In thermodynamics that was the generalization of the principle of perpetuum mobile excluded to nonthermal and noncyclic engines and the extention of applicability for the classic thermodynamic method of potentials due to introducing new characteristic nonequilibrium state function – inergy. In nonequilibrium thermodynamics such an approach enabled the consistently thermodynamic (i.e. nonhypothetical and free of postulates and statistical-mechanical considerations) substantiation of all its statements. In electrostatics and electrodynamics that approach enabled the thermodynamic derivation of the Coulomb law and Maxwell equations, the Ohm generalized law and Poynting theorem having shown the possibility of a separate description for oppositely directed fluxes of electric and magnetic fields.

Much attention is given in this section to analyze those assumptions that were primordially laid into the foundation of the aforementioned fundamental disciplines and to prove the possibility to obtain their major results by the shortest way free of historically extraneous features, hypotheses, postulates, model representations and molecular-kinetic or statistical-mechanical considerations.

The most important result of this section should be considered as the possibility of the methodologically unified exposition of all mentioned disciplines as consequences from energodynamics, which is a major contribution to the modern natural science conceptual formation.

Part 3 – Negative Consequences of Thermodynamics Extrapolation (Chapters 10-14) – exposes the contradictions arisen in thermodynamics because of the ungrounded extrapolation of the entropy rise principle to all irreversible processes without exception. Among these are, in particular, the theory of "heat death" of the Universe; the Gibbs paradox (the conclusion of inevitable "jump" of entropy when mixing non-interacting and however poorly distinguishable gases); the appearance of thermodynamic inequalities when changing to irreversible processes; the conclusion of disturbed law of excluded perpetual motion of the second kind in open, spin, relativistic, etc systems; the extension of the ban on environmental heat usage to conversion of nonthermal engines; the indistinguishability between heat and work in open systems and loss therein of free energy potential properties; the distortion of material equilibrium occurrence conditions; the introduction of negative absolute temperature; the application of the relativistic transformations to internal system parameters, etc. The sources of the difficulties arisen are exposed in each particular case and the ways to overcome them from the positions of energodynamics are indicated. It is shown here that the paralogisms mentioned result from statistical-informational entropy substituted for thermodynamic one, the relation of entropy with irreversibility and dissipation distorted and entropy rise in principle unprovable for the processes, which irreversibility is not connected with the conversion of ordered energy into thermal one. A number of other examples are given, where using the entropy criteria of evolution leads to erroneous conclusions. Conclusion is made that such criteria need to be replaced by more general state functions based on the concept of system ordered energy (inergy).

Part 4 – Thermodynamic Analysis of Phenomena at Scientific Disciplines Interfaces – offers a new method to study multiple "superposition" effects appearing at the boundary interfaces between scientific disciplines because of two and more nonstatic processes running therein simultaneously. This method allows simplifying the kinetic equations for such processes, reducing the number of empirical coefficients therein, prognosticating new relations between them without Onsager reciprocal relations and expressing the superposition effects in a number of cases exclusively in terms of thermodynamic parameters.

At the same time, this section offers the theory of nonlinear transfer processes, which extends the applicability of nonequilibrium thermodynamics to systems standing far from equilibrium.

The substantiation of the unity existing between the transfer processes of field and matter forms of energy is the subject of special attention in this section. This unity shows up in the applicability to any energy carriers (including waves and displacement current) of the same transfer equations based on the notions of motive force and generalized rate of the process. Such an approach sheds new light on the delay of potential, reveals the necessity to supplement the Maxwell equations with convective components of displacement currents, prognosticates the possibility to transmit electric power over single-wire line and the existence of longitudinal electromagnetic waves.

Part 5 – Single Theory of Energy Conversion Process Rate (Chapters 18–20) – provides the generalization of the irreversible transfer process theory to the useful energy conversion processes in thermal and nonthermal, cyclic and noncyclic, direct and reverse engines. It is shown here for the first time the unity of the any-forms-of-energy-conversion processes, which is expressed in the similarity of kinetic equations for these processes, in the generality of their efficiency criteria, in the existing universal load characteristics relating these criteria to the load and power of thermal and nonthermal, technical and nontechnical energy converters. The theory of similarity for linear energy converting systems and the theory of their productivity generalize the classic theory for thermal engines and provide its synthesis with such new branches of thermodynamics as "thermoeconomics" and " finite time thermodynamics".

It is the subject of special attention that this section proves the possibility of using the field forms of energy and creating on this basis power units of special class, which are erroneously referred to as "free energy generators", "over-unity devices" and "perpetual motion machines". The analysis of a great number of operating machines of such a type with the help of the regularities pertaining to field-forms-of-energy transfer processes as found in the previous section contributes to the termination of that suspicious attitude the "conventional" science has always experienced toward the power units of this type and their practical implementation.

Final Part 6 – Energodynamic Theory of Evolution (Chapters 21, 22) – touches upon the world outlook aspects of energodynamics. It is shown here for the first time that, despite the widespread view, the processes of system structure formation, "self-organization" and progressive evolution at any levels of the Universe run in complete agreement with thermodynamics and obey nonentropy (inergy) criteria of evolution. Concrete examples are given showing that with systems approaching equilibrium of the *i*th kind, along with the energy dissipation (ordered energy decrease), antidissipative processes are running toward ordering of other – the *j*th degrees of their freedom, and certain structures of not at all dissipative nature appear.

It is worth noting as a subject of special attention that this section describes the fundamental law of evolution for biological systems – principle of their survivability, which states that all the evolutionary processes running in such systems are directed toward extention of their life span. The principle is clearly instantiated.

The author is far from expecting that the single "hypothesis-free" theory he advances will evoke enthusiasm among the adherents of hardened concepts. Therefore the book is oriented toward an open-minded reader able to receive new ideas and keen-set for not just extending, deepening and systematizing a knowledge acquired, but rather for its critical conceptualization. The author is looking forward to gratefully accepting all remarks and proposals from such readers.