UDC 53.02:621.391:14
DOI https://doi.org/10.32782/pet-2024-1-9

Petro TROKHIMCHUCK
Ph.D., Associate Professor, Associate Professor at the Department of A.V. Svidzynskiy's Theoretical and Computer Physics, Lesya Ukrainka Volyn National University, 13 Volya Ave., Lutsk, Volyn region, Ukraine, 43025
***ORCID ID**: https://orcid.org/0000-0003-2737-0506*
***SCOPUS-AUTHOR ID:** 8383601100*

To cite this article: Trokhimchuck, P. (2024). Do pytannia pro unifikatsiiu osnovnykh zakoniv fizyky ta teorii informatsii [To question about unification the basic laws of physics and information theory]. *Physics and Education Technology*. 1, 74–79, doi: https://doi.org/10.32782/pet-2024-1-9

TO QUESTION ABOUT UNIFICATION THE BASIC LAWS OF PHYSICS AND INFORMATION THEORY

The main problems of unification the basic laws of physics and information theory are discussed. Next aspects of this problem: laws, constants and system, are analyzed. The evolution main universal physical laws from optical Ferma principle to action principle in their historical retrospective is researched. The main thermodynamical principles as Carno theorem, Prigogine-Glensdorf principle are represented. The role of physical constants in the creation universal theories is est note. Stoney and Planck system of fundamental physical constants and its place in modern theory are analyzed. The impact of the development of physical theories on the emergence and development of systems theory is shown. According to E. B. de Condillac, any set of connected elements is a system. Moreover, part of these elements are the principles by which the corresponding system was created. At the same time, the number of principles should be minimal, and preferably one. Information theory is analyzed on the basis of its universal principle – Shannon's theorem. The connection between physics and information theory is shown. For this, the theory of information-physical structures was used. A more universal unification was obtained from the generalization from L. de Broglie's formula about the equivalence of the amount of ordered and disordered information. It is shown that on the basis of a dimensionless quantity that can be interpreted both as a dimensionless action and as a dimensionless entropy, it is possible as a partial case to obtain the basic universal laws of physics and information theory. In this case, the analogy between thermodynamic and information entropy becomes more obvious. Further prospects for the development and application of the proposed methods of unification in in various branches of modern science, including verbal and non-verbal knowledge systems, are analyzed and discussed. The idea of the possibility of creating a unified system of knowledge is also expressed.

***Key words:** unification, de Broglie, Fermat, Maupertuis, Lagrange, Hamilton, Rayleigh, uncertainty principle, physics, information theory, open systems.*

Петро ТРОХИМЧУК
кандидат фізико-математичних наук, доцент, доцент кафедри теоретичної та комп'ютерної фізики імені А. В. Свідзинського, Волинський національний університет імені Лесі Українки, просп. Волі, 13, м. Луцьк, Волинська область, Україна, 43025
***ORCID ID**: https://orcid.org/0000-0003-2737-0506*
***SCOPUS-AUTHOR ID:** 8383601100*

Бібліографічний опис статті: Трохимчук, П. (2024). До питання про уніфікацію основних законів фізики та теорії інформації. *Фізика та освітні технології.* 1, 74–79, doi: https://doi.org/10.32782/pet-2024-1-9

ДО ПИТАННЯ ПРО УНІФІКАЦІЮ ОСНОВНИХ ЗАКОНІВ ФІЗИКИ ТА ТЕОРІЇ ІНФОРМАЦІЇ

Обговорюються основні проблеми уніфікації основних законів фізики та теорії інформації. Аналізуються наступні аспекти цієї проблеми: закони, константи та системи. Досліджується еволюція основних універсальних фізичних законів від оптичного принципу Ферма до принципу дії в їх історичній ретроспективі. Повторно наведено основні термодинамічні принципи, такі як теорема Карно, принцип Пригожина-Гленсдорфа. Відзначається роль фізичних констант у створенні універсальних теорій. Проаналізовано систему фундаментальних фізичних констант Стоуні і Планка та її місце в сучасній теорії. Показано вплив розвитку фізичних теорій на виникнення та розвиток теорії

систем. Згідно з Е. Б. де Кондильяком, будь-яка сукупність зв'язаних елементів є системою. Більш того, частина цих елементів є принципами, за якими була створена відповідна система. При цьому кількість принципів має бути мінімальною, а краще – однією. Теорія інформації аналізується на основі її універсального принципу – теореми Шеннона. Показано зв'язок фізики з теорією інформації. Для цього була використана теорія інформаційно-фізичних структур. Більш універсальну уніфікацію отримало узагальнення з формули Л. де Бройля про еквівалентність кількості впорядкованої та невпорядкованої інформації. Показано, що на основі безрозмірної величини, яку можна інтерпретувати як безрозмірну дію, так і як безрозмірну ентропію, можна як частковий випадок отримати основні універсальні закони фізики та теорії інформації. У цьому випадку аналогія між термодинамічною та інформаційною ентропією стає більш очевидною наглядною. Проаналізовано та обговорено подальші перспективи розвитку та застосування запропонованих методів уніфікації в різних галузях сучасної науки, включаючи вербальні та невербальні системи знань. Також висловлюється ідея про можливість створення єдиної системи знань.

Ключові слова: *уніфікація, де Бройль, Ферма, Мопертюї, Лагранж, Гамільтон, Релей, принцип невизначеності, фізика, теорія інформації, відкриті системи.*

Introduction. The problem of unifying the laws of physics and information theory is closely related to the development of theoretical and mathematical physics (Trokhimchuck, 2021). It was in physics that the first universal laws were formulated: Fermat's principle (eikonal theory) (Trokhimchuck, 2021), action principle of least action (Trokhimchuck, 2021), the second law of thermodynamics (Trokhimchuck, 2021).

In his research, C. Shannon derived a quantity that had the same properties as entropy, and on the recommendation of J. von Neumann, he named it entropy (information entropy), and the law itself was named information entropy (Shannon, 1948). At the same time, a similar law was formulated in non-equilibrium thermodynamics, which was named the Prigozhin-Glensdorff principle (Trokhimchuck, 2021). Later, Yu. Klimontovich built the theory of open systems on the basis of this principle (Trokhimchuck, 2021).

Further unification is associated with the use of L. de Broglie's formula from the thermodynamics of a point (de Broglie, 1964), which was interpreted as the principle of equality of ordered and disordered information for a closed system (Trokhimchuck, 2021). This made it possible to consider all the principles of deterministic and stochastic science from a single point of view (Trokhimchuck, 2021).

Also, on the basis of Rayleigh's principle of observability and the principle of uncertainty (Bohr, 1928), the theory of information-physical structures (Trokhimchuck, 1992) was built, which allowed a deeper understanding of the connection between theoretical physics and information theory.

On the basis of these studies, criteria were developed both for the construction of a more general theory of open systems and for the characterization of such phenomena as the vacuum (Trokhimchuck, 2021).

Physical constants play a significant role in the unification of physical laws (Barrow, 1986). Thus, the Newtonian gravitational constant is the legalization of the unification of celestial and terrestrial mechanics into a single system, and the speed of light is the unification of electricity, magnetism, and optics into Maxwellian electrodynamics.

The systems of Stoney constants (gravitational constant, speed of light in a vacuum, and electron charge) and Planck's constants (gravitational constant, speed of light in a vacuum, and Planck's constant) showed that it is possible to use dimensional analysis and an optimal set of constants to construct physical quantities that have a completely specific physical nature (plankion in modern cosmology) (Barrow, 1986).

Main results and discussions. It should be noted that besides the Newtonian synthesis program in physics there are some modifications (Trokhimchuck, 2021). In contrast to classical representations that exist in cybernetics and physics, the theory of information and physical structures is the synthesis of physical and information theory. The following problem is practically addressed: is it not possible to construct the theory so that it is based on both informational and physical laws and principles. Such a program was implemented in the theory of information and physical structures (Trokhimchuck, 1992), the main element of which is the Rayleigh ratio (Bohr, 1928). We give it in a one-dimensional form:

$$\Delta k_x \cdot \Delta x = \Delta k_y \cdot \Delta y = \Delta k_z \cdot \Delta z = \Delta\omega \cdot \Delta t = 1. \qquad (1)$$

Where Δk_x, Δx, Δk_y, Δy, Δk_z, Δz, $\Delta\omega$,$\cdot\Delta t$ – corresponding changes of wave numbers, coordinates, frequency and time.

When multiplying this relation by ħ (Planck (Dirac) constant) and changing the sign of equality to a sign greater than-equal, then we have (Bohr, 1928)

$$\Delta p_x \cdot \Delta x = \Delta p_y \cdot \Delta y = \Delta p_z \cdot \Delta z = \Delta E \cdot \Delta t \geq \hbar . \quad (2)$$

Where Δp_x, Δp_y, Δp_z – corresponding changes of liner momentum coordinates.

It is nothing more than a mathematical expression of the principle of complementarity and of the uncertainty principle.

But in quantum mechanics, ħ /2 is often written instead of ħ. This is due to the fact that "half" of uncertainty is attributed to incoherent processes. (the so-called zero states of the quantum vacuum).

If we put equal signs in formulas (1) and (2), we will get a mathematical expression of the conditions of classical and quantum coherence (Perina, 1985).

If we change the signs to differentials and use linear differential forms, we will get the theory of information-physical structures (Trokhimchuck, 1992).

Recall that the relation (1) is a condition of observation of a unit wave. In the theory of information-physical structures, it is considered as a quantum of change of dimensionless physical measure.

Thus, the relation (2), which is analogous to the Rayleigh ratio, can be regarded as a spatial-temporal representation of dimensionless entropy, as well as dimensionless action. They are equivalent to the de Broglie ratio (de Broglie, 1964)

$$\frac{S_a}{\hbar} = \frac{S_e}{k_B} = S_g \quad (3)$$

about the equality of ordered and disordered information in closed system. Here S_a is an action, S_e – entropy, $\hbar$ – Planck constant, k_B – Boltzmann constant (Trokhimchuck, 2021). Therefore, it makes sense to consider dimensionless relations not as elements of dimensionless entropy or action, but as elements of a generalized information (Trokhimchuck, 2021).

As shown in (Trokhimchuck, 2021), with this measure one can generalize the concept of physical vacuum. Indeed, in modern physics, this concept plays a very important role. There are three basic types of vacuum. This is Newtonian ether – a completely elastic environment in which all known physics interactions can be described and described; In electromagnetism (the quantum field theory also), this is a space-time continuum with $\varepsilon = 1$ and $\mu = 1$ (where ε, μ – the relative dielectric and magnetic permeability of the medium). W. Pauli (Trokhimchuck, 2021), by the way, considered an electromagnetic vacuum as a kind of ether. The third kind of vacuum is cosmological, which is main in cosmology.

In (Trokhimchuck, 2021), the view was expressed that an electromagnetic vacuum is mainly a dynamic environment, and Newtonian ether is static.

According to (Trokhimchuck, 2021), we introduce the concept of vacuum from a polymetric analysis.

Definition 1. A generalized vacuum is the state of a system in which the change of the generalized measure is zero.

Here are examples:

1. Ether of Newton – Mach. The reference system – the absolute and spatial-temporal measure is also absolute, so the change of this measure is zero.

2. Electromagnetic vacuum. Measure is the quantum of action Planck constant h, $\delta h = 0$.

3. The theory of informational-physical structures: the measure is or dimensionless entropy, or action, the vacuum states will be states with $\delta S_e = 0$ and $\delta S_a = 0$.

From the latter, the role of the principle of dynamic equilibrium is very clearly visible: it is the principle of equilibrium between physics and information. Entropic representations and the principle of dynamic equilibrium itself can be summarized as follows (for a generalized measure we denote S_g):

$$\delta S_g > 0;\ S_g > 0; \quad (4)$$

$$\delta S_g < 0;\ S_g < 0; \quad (5)$$

$$\delta S_g = 0;\ S_g = 0. \quad (6)$$

The relation (4) is nothing more than the action principle, the Carnot principle, the Prigogine-Glensdorff principle, the uncertainty principle, criterion of open systems [7, 8]. The relation (5) is a generalization of the negentropic principle of the theory of information, principles of classic and quantum coherence theories, etc. Expression (6) is the condition for the existence of vacuum: $\delta S_g = 0$ is relative, $S_g = 0$ is absolute.

It should be noted that the trends in the development of theoretical physics in XVII – XVIII centuries, in particular the principle of Fermat and Maupertuis, led to the creation of the foundations of the modern theory of systems by E. B. de Condillac (de Condillack, 2009).

Thus, in the theory of information-physical structures and in this section in terms of laws the most general unification was carried out.

Here are some thoughts on the relationship between physics and information theory. Consider a more detailed relationship $S_g = k \cdot x - \omega \cdot t$.

In fact, if $S_g > 0$, that is, $k \cdot x > \omega \cdot t$, then the structure changes, which means that over time the structural part of the measure increases, that is, it increases its entropy, action, etc. When $S_g < 0$, this means that the structural part of the measure of relatively intense (frequency-time) changes little, so physical processes pass at a different speed than information (Trokhimchuck, 2021).

As we see at the level of laws, physics and information theory are synthesized and thus, using the example of physics, they showed that any theory is also informative.

In contrast to classical representations that exist in cybernetics and physics, the theory of information and physical structures is the synthesis of physical and information theory. The following problem is practically addressed: is it not possible to construct the theory so that it is based on both informational and physical laws and principles. Such a program was implemented in the theory of information and physical structures (Trokhimchuck, 1992), the main element of which is the Rayleigh ratio. We give it in a one-dimensional form:

$$\Delta k \cdot \Delta x = \Delta \omega \cdot \Delta t = 1. \quad (1a)$$

Analogously we receive one-dimensional variant of formula (2).

$$\Delta p_x \cdot \Delta x = \Delta E \cdot \Delta t \geq \hbar. \quad (2a)$$

This is nothing more than a mathematical expression of Bohr's complementarity and the principle of uncertainty.

The main concepts of the theory of information-physical structures are:

1) the principle of fundamental harmonic equilibrium;

2) the equivalence of all canonical parameters: E – energy; p – linear momentum; k – wave number; x – coordinate; ω – frequency; t – time;

3) polymetry, that is, for each physical phenomenon corresponds to its own metric (symmetry, geometry, dimension, etc.).

Definition 1. Information-physical (dynamic) structures will be called mathematical structures (constructive), which are formed and changed under the influence of the change of any of the canonical parameters or group of parameters, or the type of functional dependence (communication) between them.

Definition 2. A dynamic structure with pure bonds is called a structure in which (Trokhimchuck, 1992)

$$k \cdot x = N_1,\ \omega \cdot t = N_2, \quad (7)$$

where N_1, N_2 – numbers.

Principle of fundamental harmonic equilibrium: When in the information-physical structure with pure bonds the form of connections does not change (does not change its dimension), the structure is in a state of harmonic equilibrium.

Principle of dynamic equilibrium: A structure is called dynamically equilibrium if

$$k \cdot x - \omega \cdot t = 0 \quad (8)$$

or

$$k \cdot x = \omega \cdot t. \quad (9)$$

Roughly speaking, correlations (7) and (8) are expanded Rayleigh correlation (ratio).

Now we rewrite Rayleigh ratio (1 a) and (2 a):

$$\Delta k \cdot \Delta x = \Delta \omega \cdot \Delta t, \quad (10)$$

$$\Delta p_x \cdot \Delta x = \Delta E \cdot \Delta t. \quad (11)$$

We replace the operator Δ on a differentiatial d. If only the parameter under the differential does not go to zero, then this substitution is mathematically correct. In this case we have

$$dk \cdot dx = d\omega \cdot dt,\ dp_x \cdot dx = dE \cdot dt, \quad (12)$$

or equivalent

$$\frac{dx}{dt} = \frac{d\omega}{dk} = const,\ \ \frac{dx}{dt} = \frac{dE}{dp_x} = const. \quad (13)$$

Integrating (13), with $const = V$ (speed) we have

$$E = p_x V + C_1;\ x = Vt + C_2;\ \omega = kV + C_3; \quad (14)$$

where C_1, C_2, C_3 – integration constants. Having put $C_1 = E_0$, $C_2 = x_0$, $C_2 = x_0$, $C_3 = \omega_0$, we have

$$E = p_x V + E_0;\ \ x = Vt + x_0;\ ;\ \omega = kV + \omega_0; \quad (15)$$

that is nothing else than the law of conservation of energy, the law of inertia and the law of addition of frequencies, and also the law of constant interaction velocity in an isotropic medium (relation (13). In an electromagnetic environment, this will be the speed of light c. If in the first case, replace V on c, and E_0 on $m_0 c^2$, where m_0 – the initial mass of the moving body, then we have

$$E = p_x V \pm m_0 c^2, \quad (16)$$

that is, the law of conservation of energy in an isotropic electromagnetic environment.

Further, the expansion of the relation (8) is carried out through the harmonic potential (Trokhimchuck, 1992)

$$\varphi = \varphi_0 exp\left\{i\left(kx - \omega t\right)\right\}. \qquad (17)$$

As shown in (Trokhimchuck, 1992), is nothing more than a dimensionless entropy; for large values of parameters it becomes equal to Boltzmann or Shannon (in more detail it is disassembled in (Trokhimchuck, 1992) entropy, that is

$$S_e = kx - \omega t\,. \qquad (18)$$

We can change S_e on δS_e, then we have for $\delta S_e = kx - \omega t > 0$ the law of increasing the entropy, and for $\delta S_e = kx - \omega t < 0$ – the negentropic principle of information theory.

It should be noted that cybernetics is also a synthetic science [George, 1979], which, in addition to physics and information theory, includes a number of other sciences. In general, it should be an open system. Therefore, the theory of information-physical structures removes part of the problems in creating a more universal theory – polymetric analysis (a universal theory of analysis and synthesis of any knowledge system) (Trokhimchuck, 2021).

But $kx - \omega t$ and $px - Et$ is also a wave phase and entropy can be replaced by action. In particular, this was reflected in the construction of the Lagrangian formalism of quantum mechanics (Trokhimchuck, 2017).

As we see at the level of laws, physics and information theory are synthesized.

Conclusions:

1. The problem of unification physical laws is researched.
2. The influence of these studies on the further unification of the laws of physics and information theory is shown.
3. The theory of informational and physical structures is analyzed.
4. Questions about the perspectives for the development of this direction of research are discussed.

REFERENCES:

1. Barrow, J.D., & Tippler, F. (1986). The Anthropic Cosmological Principle. Oxford: University Press, 676 p.
2. Bohr, N. (1928). *The Quantum Postulate and the Recent Development of Atomic theory*. Nature, Supplement, Vol.121, pp.580–590.
3. De Broglie, L. (1964). Thermodynamics of isolated point (Hidden thermodynamics of particles). Paris: Gauthiers Villars, 104 p.
4. De Condillac, E.B. (2009). A treatise about systems. (Traite des systemes), New York: Kessinger Publishing, 127 p.
5. George, F.H. (1979). Philosophical foundations of cybernetics. Tunbridge Wells: Abacus Press, 157 p.
6. Perina, J. (1985). Coherence of light. Berlin: Springer Verlag, 1985. 350 p.
7. Shannon, C. (1948). *Mathematical Theory of Communications*, The Bell System Technical Journal, vol. 27, pp. 379–423, 623–656.
8. Trokhimchuck, P.P. (2017). Teoretychna fizyka [Theoretical Physics]. Lutsk: Vezha-Print, 260 p.
9. Trokhimchuck, P.P. (2021). Theories of Everything: Past, Present, Future. Saarbrukken: Lambert Academic Publishing, 260 p.
10. Trokhimchuck, P.P. (1992). Teoriia optymalnykh dynamichnykh (informatsiino-fizychnykh) struktur [Theory of optimal dynamic (information-physical) structures]. Reports of Ukrainian Academy of Science, № 1, pp.22–25 [in Ukrainian].

BIBLIOGRAPHY:

1. Barrow J. D., Tippler F. The Anthropic Cosmological Principle. Oxford: University Press, 1986, 676 p.
2. Bohr N. *The Quantum Postulate and the Recent Development of Atomic theory*.// Nature, Supplement, 1928,121: 580–590.
3. De Broglie L. Thermodynamique du point isolé (Thermodynamique cachée des particules). Paris: Gauthiers Villars, 1964, 104 p.
4. De Condillac E. B. Traite des systemes. New York: Kessinger Publishing, 2009, 127 p.
5. George F. H. Philosophical foundations of cybernetics. Tunbridge Wells: Abacus Press, 1979, 157 p.
6. Perina J. Coherence of light. Berlin: Springer Verlag, 1985. 350 p.
7. Shannon C. Mathematical Theory of Communications, The Bell System Technical Journal, 1948, 27: 379–423, 623–656.

8. Трохимчук П. П. Теоретична фізика. Луцьк: Вежа-Друк, 2017. 260 с.
9. Trokhimchuck P. P. Theories of Everything: Past, Present, Future. Saarbrukken: Lambert Academic Publishing, 2021. 260 p.
10. Трохимчук П. П. Теорія оптимальних динамічних (інформаційно-фізичних) структур. Доповіді Академії наук України, 1992, № 1: 22–25.