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BIOLOGICAL SCIENCES

SYNTHESIS AND IR-SPECTROSCOPIC ANALYSIS OF A HIGH-INTENSITY NICKEL PHTHALOCYANINE PIGMENT CONTAINING NITROGEN AND SULFUR

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Abstract

This study reports the synthesis of a high-intensity nickel phthalocyanine pigment containing nitrogen and sulfur, characterized by the incorporation of macroheterocyclic structures. The pigment was comprehensively investigated to assess the role of macroheterocyclic frameworks in enhancing its optical and structural properties. The absorption regions were analyzed using modern physicochemical techniques based on IR spectroscopy. The results confirmed that the cyclic bonding patterns contribute to the formation of a complex structural framework, providing new insights into the structural characteristics and potential applications of nitrogen- and sulfur-containing nickel phthalocyanine pigments.

Keywords: nickel phthalocyanine, macroheterocyclic structures, nitrogen, sulfur, IR spectroscopy, high-intensity pigment.

Introduction

Phthalocyanines (Pc) are macroheterocyclic compounds consisting of four isoindole rings interconnected through sp^2 -hybridized nitrogen atoms (Fig. 1).

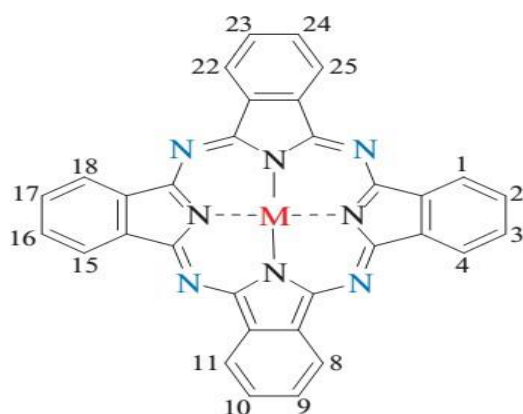
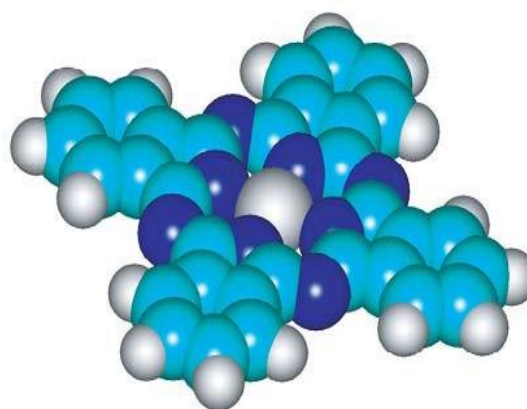


Figure 1. Phthalocyanine compound.



Phthalocyanines are considered a special class of macroheterocyclic compounds that share structural similarities with porphyrins and are distinguished by their remarkable chemical stability and extended π -conjugation. Various derivatives can be synthesized depending on the selected synthetic approach, including symmetric, asymmetric, and metal-free phthalocyanines. The synthetic process is largely determined by several factors: the type of precursor used, the metal source (metals, salts, oxides, sulfates, or halides), solvent characteristics, temperature conditions that pro-

mote precursor dissolution and facilitate rapid cyclotetramerization, as well as the role of bases and catalysts [1-2].

Among the most common precursors are phthalonitriles, phthalimides, phthalic acids, and phthalic anhydrides, which, through cyclotetramerization, produce phthalocyanines. When suitable metal salts are present, this process leads to the formation of metallophthalocyanines. These metallated derivatives are of great interest because of their enhanced optical and electronic features, which can be tailored by modifying both the central metal ion and the peripheral substituents.

Numerous studies have demonstrated the wide-ranging potential of phthalocyanines and their metal complexes. Unsubstituted metallophthalocyanines, for example, have long been utilized as industrial pigments due to their durability and strong coloration [3]. Investigations that are more recent emphasize the development of functionalized PCs containing electron-donating or electron-withdrawing groups, which allow for adjustment of HOMO–LUMO levels and improvement in solubility [4-5]. Transition-metal phthalocyanines - including those of Co, Cu, Ni, and Zn - have shown excellent catalytic activity in oxygen reduction and hydrogen evolution reactions [6]. Moreover, their use as semiconducting materials in thin-film transistors, organic photovoltaics, and photodynamic therapy has been extensively reported [7-9].

Because of their flexible structural framework, ease of synthesis, and highly tunable physicochemical

properties, phthalocyanines remain an area of intensive research interest, providing a strong basis for the advancement of next-generation functional materials.

Great interest lies in the development of multi-component ensembles composed of phthalocyanines and other molecules or nanomaterials. Such hybrid materials hold significant potential for the creation of photoactive systems applicable in photoelectronics and photovoltaics. At present, numerous examples have been reported describing ensembles of phthalocyanines with a wide variety of molecules, and different strategies have been developed for the covalent “grafting” of phthalocyanines onto polymers, carbon nanotubes, fullerenes, and grapheme[10]. To achieve this, it is necessary to introduce anchoring functional groups into the phthalocyanine molecules, which are capable of undergoing further chemical modification (Fig. 2).

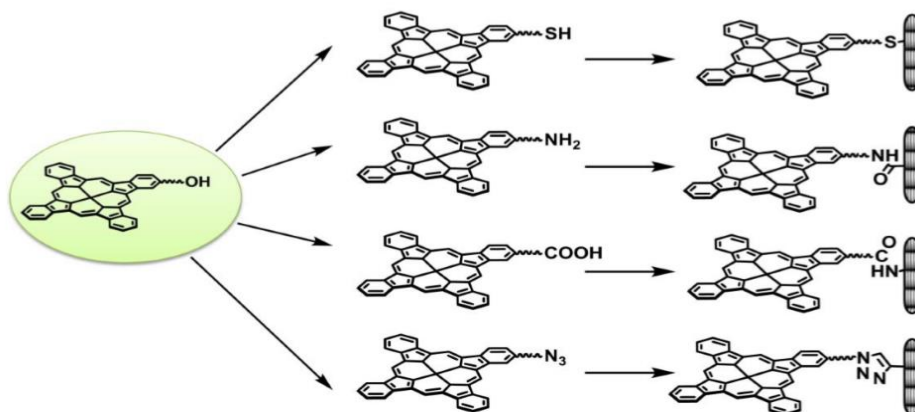


Figure 2. Grafting of phthalocyanines onto the surface of nanomaterials through various anchoring functional groups.

One such group is the hydroxyl group R–OH, which can subsequently be transformed by organic chemistry methods into a carboxyl, amide, thiol group, and so on [11].

An interesting example of such an anchoring group is the azide group. The Cu(I) salt-catalyzed

“click” reaction of 1,3-dipolar cycloaddition between an alkyne and the azide group within the phthalocyanine framework results in the formation of a triazole, which links two structural fragments[12]. This reaction has been employed to obtain a functionalized polymer containing phthalocyanine fragments (Fig. 3).

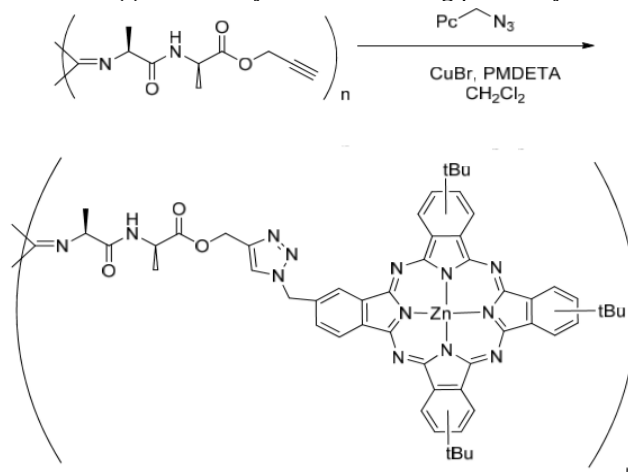


Figure 3. Synthesis of a phthalocyanine-containing polymer via 1,3-dipolar cycloaddition of a zinc phthalocyanine bearing an azide group with a polymer containing an acetylene group [14].

Materials and Methods

In the synthesis of the organic metal phthalocyanine pigment, 250 ml heat-resistant glass vessel, 7 mol

of urea, 1 mol of phthalic anhydride, and 2 mol of ammonium sulfate were measured and melted in a muffle furnace using an electric heater until a homogeneous mass was obtained. Subsequently, 1 mol of nickel (II)

chloride and a catalyst were added to the melt, and the temperature was raised to 140 °C. At first, a yellowish coloration appeared which then gradually transformed into an attractive dark green mass. The mixture was stirred with a glass rod, and after 10–15 minutes the viscosity increased, leading to solidification of the reaction mass, which was then cooled. The product was placed in a laboratory-heating furnace at 260 °C for 2 hours, followed by cooling to room temperature. The resulting powdery reaction mixture was cooled to 50 °C and dissolved in 90% sulfuric acid. Upon the addition of boiling water with stirring, unreacted starting materials and intermediate products were separated. The composite mixture was washed several times with distilled water until neutralized. The resulting NiSPc pigment precipitated out. The precipitated phthalocyanine pigment was filtered and dried in a ShS-8001 ShSU drying oven at 90 °C, completing the exothermic reaction of NiSPc formation.

Results and Discussion

During the synthesis, the maximum temperature reached 270 °C. As a result, NiSPc was obtained with

a stoichiometric yield of 72.7%. Infrared spectroscopy (IR) measurements were performed using an IR Tracer-100 FTIR spectrophotometer. This technique was employed to identify functional groups and assess the purity and structural characteristics of the synthesized compounds. FTIR analysis was carried out by recording the absorption of infrared radiation relative to a reference, and the obtained spectra were used for molecular identification. The instrument allows extension of the spectral range from the near-infrared region (up to 12,500 cm^{-1}) to the far-infrared region (down to 240 cm^{-1}). With a high signal-to-noise ratio of 60,000:1, the spectrometer ensures reliable detection of even low-intensity absorption bands, enabling accurate analysis of trace components and confirming the structural features of the investigated pigments. Figure 4 illustrates the results of the IR spectral analysis, clearly showing the characteristic absorption bands that confirm the presence of functional groups within the synthesized pigment.

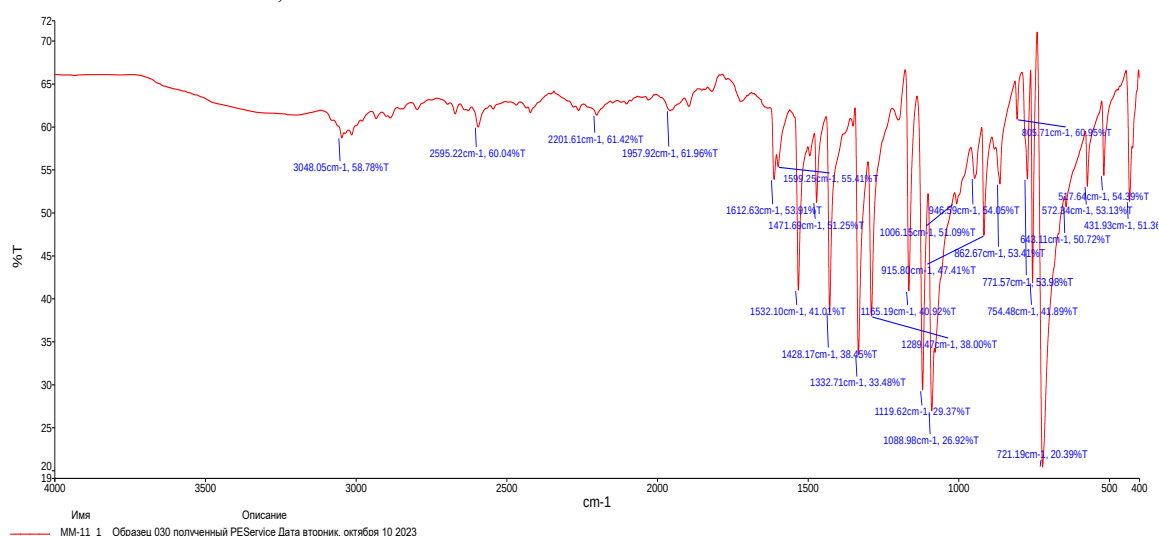


Figure 4. IR spectral analysis of the synthesized nickel phthalocyanine pigment (NiSPc).

The IR spectral analysis of the synthesized pigment revealed characteristic absorption bands that confirm the successful formation of the phthalocyanine macrocyclic framework. The broad absorption in the 3200–3400 cm^{-1} region corresponds to N–H stretching vibrations, which are typical for phthalocyanine structures. The peaks observed around 2900–3000 cm^{-1} are attributed to C–H stretching vibrations, indicating the presence of both aromatic and aliphatic hydrocarbon fragments.

A strong band in the 1600–1650 cm^{-1} region is assigned to C=N stretching vibrations, confirming the presence of a conjugated system within the phthalocyanine macrocycle. Similarly, the absorption between 1500–1550 cm^{-1} corresponds to C=C aromatic stretching, further supporting the aromatic character of the compound.

The absorption peaks detected in the 1300–1450 cm^{-1} range are associated with C–N stretching vibrations, which demonstrate the successful formation of the macroheterocyclic structure. The 1000–1250 cm^{-1} region showed C–H bending vibrations of the aromatic

ring, with possible contributions from S–O stretching, indicating the incorporation of sulfur into the molecular framework. Finally, the peaks appearing in the 700–900 cm^{-1} region correspond to out-of-plane C–H bending vibrations of the aromatic ring, serving as a clear indicator of the established phthalocyanine ring system.

These spectral features collectively confirm the structural integrity of the synthesized nitrogen- and sulfur-containing nickel phthalocyanine pigment and provide strong evidence for the formation of a stable macroheterocyclic complex.

Conclusion

The IR spectral analysis provided clear evidence for the successful synthesis of the nickel phthalocyanine pigment. The characteristic absorption bands corresponding to C=N, C=C (aromatic), and C–N stretching vibrations confirm the formation of the intended macroheterocyclic phthalocyanine framework. In addition, the presence of distinct N–H stretching vibrations in the higher frequency region further validates the complete formation and structural stability of the macrocyclic system. These findings demonstrate that the

synthesized pigment possesses the expected molecular architecture, supporting its potential application in advanced material systems.

References:

1. Yusupov, M., & Kadirhanov, J. (2023). In E3S Web of Conferences (Vol. 390). EDP Sciences.
2. M Yusupov, O Kayumjanov. Synthesis of metal phthalocyanine pigment based on npk and calculation of particle size using the debye-scherrer equation / Scientific and Technical Journal of Namangan Institute 2024. P.122-126
3. Dinçer, H. A., *et al.* (2007). *Tuning of phthalocyanine absorption ranges by additional substituents. Dyes and Pigments*. ScienceDirect
4. Mirshokraee, S. A., *et al.* (2024). *Ni-Phthalocyanine Derived Electrocatalysts for Oxygen ACS Catalysis*. ACS Publications
5. Selvam, S. P., *et al.* (2025). *A multifaceted DFT study of electronic and optical properties*. ScienceDirect
6. Bednarik, S., *et al.* (2024). *Tuning Electron-Accepting Properties of Phthalocyanines for Inorganic Chemistry*. ACS Publications
7. Abbaspour, A., *et al.* (2013). *Electrocatalytic activity of iron and nickel phthalocyanines supported on multi-walled carbon nanotubes towards oxygen evolution reaction. Journal of Electroanalytical Chemistry*. ScienceDirect
8. Han, J., *et al.* (2024). *Graphite-conjugated nickel phthalocyanine for efficient CO₂ reduction. Chemical Science*. RSC Публикации
9. Farley, C., *et al.* (2016). *Tuning the Structure and Photophysics of a Fluorous-Phthalocyanine Derivative Series, Journal of Physical Chemistry*. PMC
10. Bottari G. Phthalocyanine-nanocarbon ensembles: From discrete molecular and supramolecular systems to hybrid nanomaterials / G. Bottari, G. de la Torre, T. Torres // *Acc. Chem. Res.* – 2015. – Т. 48 – № 4 – 900–910с.
11. Berthold H.J. Ex post glycoconjugation of phthalocyanines / H. J. Berthold, S. Franke, J. Thiem, T. Schotten // *J. Org. Chem.* – 2010. – Т. 75 – № 11 – 3859–3862с.
12. Berthold H.J. A highly versatile octasubstituted phthalocyanine scaffold for ex post chemical diversification / H. J. Berthold, T. Schotten, F. Hoffmann, J. Thiem // *Synthesis (Stuttg.)*. – 2010. – № 5 – 741–748с.
13. López-Duarte I. Postfunctionalization of helical polyisocyanopeptides with phthalocyanine chromophores by «click chemistry» / I. López-Duarte, M. V. Martínez-Díaz, E. Schwartz, M. Koepf, P. H. J. Kouwer, A. E. Rowan, R. J. M. Nolte, T. Torres // *Chempluschem* – 2012. – Т. 77 – № 8 – 700–706с.

CHEMICAL SCIENCES

PHYSICO-CHEMICAL INVESTIGATION OF PHASE EQUILIBRIUM AND GLASS FORMATION IN THE AsS-Cu₂Cr₄Te₇ SYSTEM

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Abstract

Phase formation and vitrification in the AsS-Cu₂Cr₄Te₇ system are studied by the methods of physical and chemical analysis: differential thermal (DTA), X-ray diffraction (XRD), microstructural (MKA), and also determination of microhardness and density. The T-x phase diagram is constructed. It is established that the AsS-Cu₂Cr₄Te₇ system is a partially quasibinary section. Based on the results of the microstructural analysis, it was established that in the AsS-Cu₂Cr₄Te₇ system at room temperature, the solubility of 12 mol.% AsS based on the Cu₂Cr₄Te₇ compound was found, while the area of the solid solution based on the AsS compound is practically undefined. During slow cooling in the AsS-Cu₂Cr₄Te₇ system, a region of glass formed on the basis of AsS 10 mol. % Cu₂Cr₄Te₇. The area of AsS-based glass when cooled in ice water is 15 mol.% Cu₂Cr₄Te₇. In the interval of concentrations of 10–30 mol. % Cu₂Cr₄Te₇ there are alloys of glass crystal composition.

Keywords: peritectic, quasibinary, glass, solid solution, microhardness.

Introduction

Arsenic chalcogenides, one of the main elements of Group V, are known to form in a glassy state. Recently, arsenic chalcogenides, as well as complex glassy alloys and compounds based on them, have attracted the attention of researchers due to their unique functional properties. Arsenic chalcogenides, as well as complex glassy alloys and compounds based on them, are widely used in various fields of photoelectronics as photosensitive, luminescent, and acousto-optic materials [1–8]. Chromium chalcogenides form magnetic materials with a number of chalcogenides, including copper chalcogenides [9–15].

We have studied a number of systems involving the compound Cu₂Cr₄Te₇ [16, 17]. The physical properties of arsenic monosulfide AsS remain virtually unexplored. Therefore, it can be expected that new complex phases and glassy alloys obtained by the chemical interaction of AsS and Cu₂Cr₄Te₇ chalcogenides can also be semiconductor materials with magnetic and magneto-optical properties.

The aim of this work is to conduct a physicochemical study of the phase equilibrium in the AsS-Cu₂Cr₄Te₇ system, construct its phase diagram, and determine the glass transition and solid solution boundaries.

The glassy compound AsS melts at 318°C with an open maximum and crystallizes in the orthorhombic syngony, with lattice parameters: $a = 9.32$; $b = 13.546$;

$c = 6.585 \text{ \AA}$ [18]. The compound Cu₂Cr₄Te₇ melts incongruently at 1000°C and has a wide homogeneity region [15].

Experimental Section

The synthesis of AsS-Cu₂Cr₄Te₇ alloys was carried out in two stages. In the first stage, AsS and Cu₂Cr₄Te₇ compounds were synthesized using the ampoule method. The AsS compound was obtained from the elements in a single-zone furnace at a temperature of 400–700°C. The AsS compound was obtained as a glass with normal cooling. A two-zone furnace was used to obtain the Cu₂Cr₄Te₇ compound from the elements. To synthesize the Cu₂Cr₄Te₇ compound of the AsS-Cu₂Cr₄Te₇ system, elements taken in stoichiometric composition are placed in a 20-cm-long ampoule. To synthesize the Cu₂Cr₄Te₇ compound, part of the ampoule is inserted into a furnace at 1100°C. The remaining portion of the ampoule is left outside the furnace. During this process, Te vapor initially begins to form. This process continues until the Te vapor disappears. After maintaining the reaction at 1100°C for 3 hours, the furnace temperature is increased to 950°C, held for 4 hours, and then cooled by disconnecting it from the power source. In the second stage, the AsS-Cu₂Cr₄Te₇ alloys were synthesized from the AsS and Cu₂Cr₄Te₇ compounds using the ampoule method. The alloys of the system are then analyzed using physicochemical methods.

Differential-thermal analysis was performed on a Thermoscan-2 pyrometer. Chromel-alumel was used as a thermocouple, and the heating rate was 5°C/min.

Microstructural analysis was performed on an MIM-8 microscope. $\text{HNO}_3 + \text{HF}$ solutions (1:2) were used as etchants to reveal phase boundaries in the samples. X-ray phase analysis of the alloys was performed on a D2 PHASER X-ray diffractometer. $\text{CuK}\alpha$ radiation and a Ni filter were used as the anode.

Microhardness was measured on a PMT-3 metallographic microscope. Density was determined pycnometrically, using toluene as the filler solution.

Results and Discussion

Alloys of the $\text{AsS-Cu}_2\text{Cr}_4\text{Te}_7$ system are compact, and their color ranges from red to black. The alloys of the system are resistant to air, water, and organic solvents. They are highly soluble in strong acids (HNO_3 , H_2SO_4). Alloys rich in AsS are soluble in alkalis (NaOH , KOH).

It should be noted that the physicochemical analyses of the alloys were carried out in both the crystalline and glassy states. Thermal analysis of the alloys before heat treatment revealed that thermal effects were

observed in the thermograms of samples in the range of 0–15 mol. % $\text{Cu}_2\text{Cr}_4\text{Te}_7$ at a temperature of 170°C , which corresponds to the softening temperature of glass. The composition of the alloys of the system was studied by microstructural analysis, and it was found that there is a wide range of solubility in the region of the $\text{Cu}_2\text{Cr}_4\text{Te}_7$ compound. The microstructures of the alloys in the range of 0–15 mol. % $\text{Cu}_2\text{Cr}_4\text{Te}_7$ appear as opaque single-phase. Microstructural analysis revealed that only single-phase alloys were obtained based on the $\text{Cu}_2\text{Cr}_4\text{Te}_7$ compound. Figure 1 shows the microstructure of alloys with concentrations of 40, 70, and 90 mol. % $\text{Cu}_2\text{Cr}_4\text{Te}_7$. As can be seen from the figure, alloys with concentrations of 40 and 70 mol. % $\text{Cu}_2\text{Cr}_4\text{Te}_7$ are two-phase. The alloy with a concentration of 90 mol. % $\text{Cu}_2\text{Cr}_4\text{Te}_7$ is single-phase and represents a solid solution based on the $\text{Cu}_2\text{Cr}_4\text{Te}_7$ compound.



Fig. 1. Microstructure of $\text{AsS-Cu}_2\text{Cr}_4\text{Te}_7$ alloys.
1–40 mol. %, 2–70 mol. %, 4–90 mol. % $\text{Cu}_2\text{Cr}_4\text{Te}_7$.

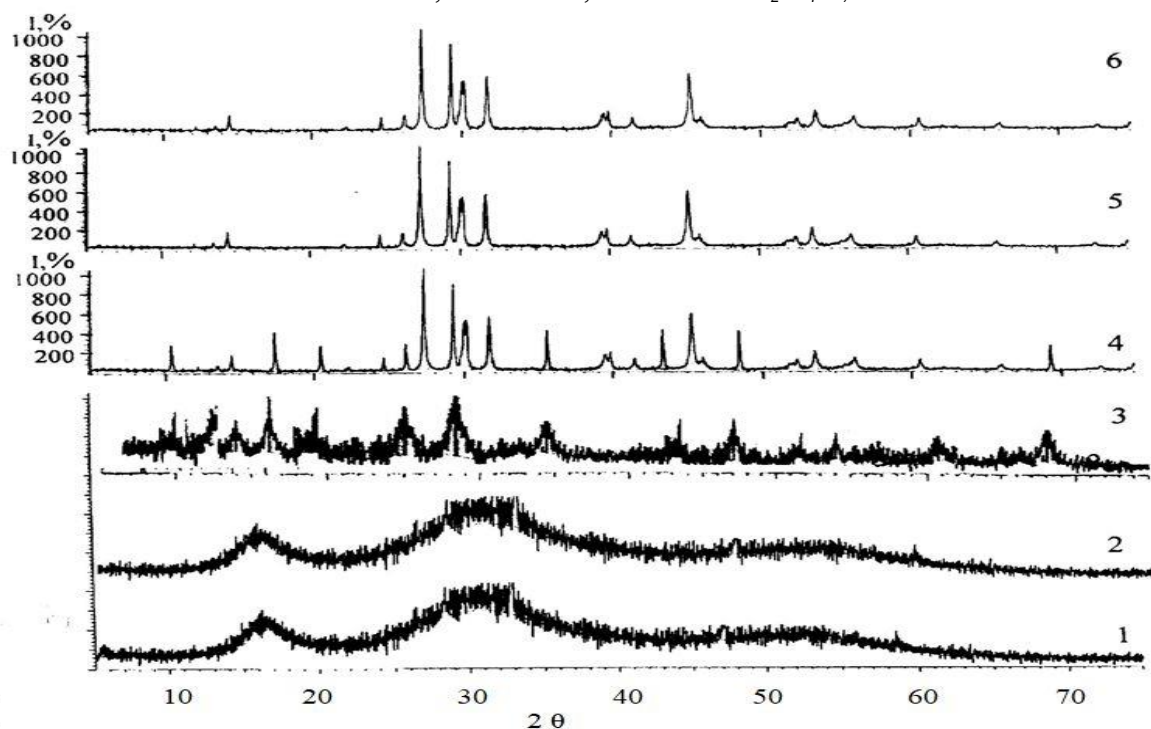


Fig. 2. X-ray diffraction patterns of $\text{AsS-Cu}_2\text{Cr}_4\text{Te}_7$ alloys.
1–5, 2–10, 3–30, 4–50, 5–90, 6–100 mol. % $\text{Cu}_2\text{Cr}_4\text{Te}_7$.

To clarify the results of differential thermal and microstructural analyses of $\text{AsS-Cu}_2\text{Cr}_4\text{Te}_7$ alloys, X-ray diffraction analysis was performed on alloys with contents of 5, 10, 30, 50, and 90 mol. % $\text{Cu}_2\text{Cr}_4\text{Te}_7$ (Fig.

2). Diffraction maxima in the diffraction patterns of alloys in the range of 0–30 mol. % $\text{Cu}_2\text{Cr}_4\text{Te}_7$ in the studied system revealed weak lines.

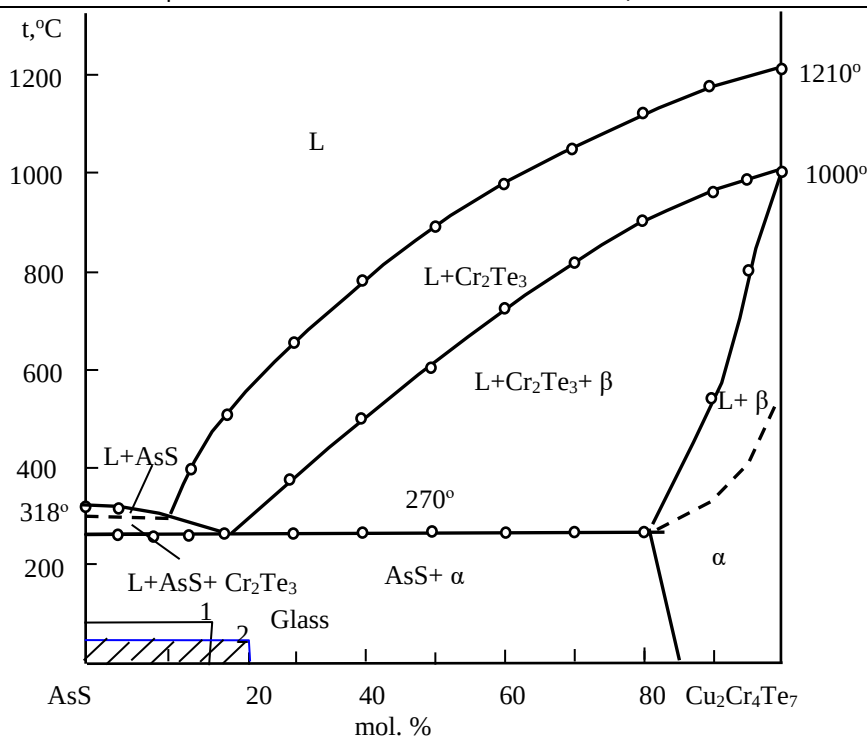


Fig.3. *T-x* phase diagram of the AsS-Cu₂Cr₄Te₇ system.
1- during slow cooling, 2- during cooling in ice water, glass area

Table 1.

Physico-chemical properties of glassy alloys of the AsS-Cu₂Cr₄Te₇ system (glass region)

Composition, mol. %		Thermal effects, °C			Microhardness, MPa	Density, q/cm ³	MSA
AsS	Cu ₂ Cr ₄ Te ₇	T _g	T _{crus.}	T _{melt.}			
100	0	170	220	318	1350	3,35	Șüşə
97	3	170	220	315	1380	3,55	—
95	5	175	230	315	1380	3,60	—
93	7	180	235	320	1380	3,67	—
90	10	190	240	270	1385	3,72	—
85	15	190	245	400	1390	3,90	Glass-crust
80	20	190	250	510	1400	4,10	Glass-crust
70	30	190	265	380	1430	4,47	Glass-crust
60	40	190	270	450	1440	4,85	crustal

This indicates the glassy nature of the samples in this region. Diffraction maxima were observed in the X-ray diffraction patterns of alloys containing 50 and 90 mol.% Cu₂Cr₄Te₇. Analysis revealed that the diffraction lines in the diffraction pattern of the sample containing 90 mol. % Cu₂Cr₄Te₇ are identical to those of the Cu₂Cr₄Te₇ compound, indicating that this sample is a solid solution alloy based on Cu₂Cr₄Te₇.

Based on the results of a comprehensive physico-chemical analysis, a phase diagram of the AsS-Cu₂Cr₄Te₇ system was constructed (Fig. 3). In the AsS-

Cu₂Cr₄Te₇ system, glassy AsS-based alloys with a composition of 10 mol. % Cu₂Cr₄Te₇ formed upon slow cooling. Alloys with a glassy-crystalline composition are present in the layer range of 10–30 mol. % Cu₂Cr₄Te₇. Table 1 shows the compositional dependences of the softening and crystallization temperatures, microhardness, and density of alloys from the glassy and glassy-crystalline regions. Table 2 presents some physicochemical properties of the alloys in the crystalline state of the system.

Table 2.

Composition, results of differential thermal analysis, determination of microhardness and density of AsS-Cu₂Cr₄Te₇ system alloys in crystalline form

Composition, mol. %		Thermal effects, °C	Density, q/cm³	Microhardness, MPa	
AsS	Cu₂Cr₄Te₇			AsS	α
				0,15 H	0,20 H
100	0,0	318	3,52	660	-
95	5,0	270,315	3,60	700	-
90	10	270	3,75	720	-
85	15	270,400	4,05	740	-
80	20	270,510	4,24	-	-
70	30	270,380,650	4,59	-	-
60	40	270,450,780	4,95	-	2000
50	50	270,600,890	5,33	-	2000
40	60	270,720,975	5,67	-	2000
30	70	270, 810,1050	6,03	-	2000
20	80	270,900,1120	6,38	-	2000
10	90	545,960,1175	6,74	-	2000
5,0	95	800,980	7,22	-	2000
0.0	100	1000,1210	7,10	-	1970

The liquidus of the AsS-Cu₂Cr₄Te₇ system represents the initial crystallization curves of the β -solid solution obtained from Cu₂Cr₄Te₇. In the system, primary crystals of the AsS compound precipitate in the range of 0–20 mol. % Cu₂Cr₄Te₇. The system undergoes a process of eutectic equilibrium and peritectic transformation.

The decomposition of the Cu₂Cr₄Te₇ compound results in the formation of three-phase alloys consisting of (L + AsS + Cr₂Te₃) and (L + Cr₂Te₃ + β). Since the peritectic process $L + Cr_2Te_3 \leftrightarrow Cu_2Cr_4Te_7$ occurs, two-phase alloys consisting of AsS + α crystallize below the solidus line in the system.

The microhardness and density of AsS-Cu₂Cr₄Te₇ alloys were studied as a function of their composition in the glassy and crystalline states (Tables 1 and 2).

Two different microhardness values were determined in the system. Before heat treatment, i.e. in the glassy state, the microhardness and density of glasses obtained on the basis of AsS are $H_\mu = (1350-1440)$ MPa, $\rho = (3.35-4.85)$ g/cm³, for α -solid solutions based on the compound Cu₂Cr₄Te₇ the microhardness is $H_\mu = (2750-2800)$ MPa, and the density $\rho = 3.52-7.22$ g/cm³. After heat treatment, the microhardness of samples from the glassy region is $H_\mu = (660-740)$ MPa, $\rho = (3.53-4.59)$ g/cm³. The microhardness and density of the crystalline phases do not change. It was found that during the glass-crystal transition the hardness of the alloys decreases and their specific gravity increases.

Conclusion

Thus, based on the results of comprehensive physicochemical analysis methods, a phase diagram of the AsS-Cu₂Cr₄Te₇ system has been constructed. The phase diagram of the system is partially quasi-binary and belongs to the eutectic type. The system undergoes eutectic equilibrium and peritectic transformation, leading to the crystallization of two-phase alloys of the AsS + α composition below the solidus line.

In the AsS-Cu₂Cr₄Te₇ system, the AsS-based solid solution region is virtually undefined. The Cu₂Cr₄Te₇-

based solid solution region is 15 mol. % AsS. The glass transition region of the AsS-based system under normal conditions is determined to be 10 mol. % Cu₂Cr₄Te₇. After cooling in ice water, the glass transition region of the AsS-based system is 15 mol. % Cu₂Cr₄Te₇. The dependence of the softening temperature T_g, crystallization T_{crys.}, microhardness and density of glassy region alloys on the composition was studied.

References:

1. Dinesh Chandra SATI1, Rajendra KUMAR, Ram Mohan MEHRA Influence of Thickness Oil Optical Properties of a: As₂Se₃ Thin Films // Turk J Phys. 2006. V.30. P.519- 527.
2. Lovu M., Shutov S., Rebeja S., Colomeyco E., Popescu M. Effect of metal additives on photodarkening kinetics in amorphous As₂Se₃ films // Journal of Optoelectronics and Advanced Materials 2000. V. 2. Issue: 1. P 53-58/
3. Jun J. Li Drabold. D. A. Atomistic comparison between stoichiometric and nonstoichiometric glasses: The cases of As₂Se₃ and As₄Se₄ // Phys. Rev. 2001. V. 64. P. 104206-104213.
4. Hineva T., Petkova T., Popov C., Pektov P., Reithmaier J. P., Funrmann-Lieker T., Axente E., Sima F., Mihailescu C. N., Socol G., Mihailescu I. N. Optical study of thin (As₂Se₃)_{1-x}(AgI)_x films // Journal of optoelektronics and Advanced Materials. 2007.Vol.9. No. 2. February. P. 326-329.
5. Seema Kandpal, Kushwaha R. P. S. Photoacoustic spectroscopy of thin films of As₂S₃, As₂Se₃ and GeSe₂ // Indian Academy of Sciences. PRAM ANA journal of physics. 2007. Vol. 69. No. 3 P. 481-484.
6. Littler I. C. M., Fu L. B., Mägi E. C., Pudo D., Eggleton B. J. Widely tunable, acoustooptic resonances in Chalcogenide As₂Se₃ fiber // Optics Express. 2006.V. 14. Issue 18. P. 8088- 8095.
7. Babaev A. A., Muradov R., Sultanov S. B., Askhabov A. M. Influence of production conditions on the optical and photoluminescent properties of glassy

As₂S₃ // Inorganic materials. 2008. Vol. 44. No. 11. P. 1187-1201.

8. Kim B.Y., Blake J.N., Engan H.E., Shaw H.J. All-fiber acousto-optic frequency shifter // Opt. Lett. 1986. V. 11. P. 389-391.

9. Lee S.S., Kim H.S., Hwang I.K., Yun S.H. Highly-efficient broadband acoustic transducer for all-fiber acousto-optic devices // Electron. Lett. 2003. V. 39. P. 1309-1310.

10. Engan H.E. Acousto-optic coupling in optical Fibers // IEEE Ultrasonics Symposium. 2000. V.1. P. 625-629.

11. Diez A., Birks T.A., Reeves W.H., Mangan B.J., St P. Russell J. Excitation of cladding modes in photonic crystal fibers by flexural acoustic waves // Optics Lett. 2000. V. 25. P. 1499-1501.

12. Claytor T.N., Sladek R.J. Ultrasonic velocities in amorphous As₂S₃ and As₂Se₃ between 1.5 and 296 K. // Phys. Rev. 1978. B. 18. P. 5842-5850.

13. Belov K.P., Tretyakov Yu.D., Gordeev I.V., Koroleva L.I., Pedko A.V., Bagorova S.D., Alferov V.A., Saksonov Yu.G., Shalimova M.A. Magnetic properties of chalcogenide spinels Cd_xCu_xCr₂S₄, CdCr₂Se_{4-y} FeCr₂S_{4-y} // FTT 1973. Vol. 15, No. 10. P. 3106-108.

14. North G.N. Anomalous photomagnetolectric effect in the ferrimagnetic semiconductor CdCr₂Se₄ // FTP. 1983. T. 17. No. 8. P.1505-507.

15. Shumilkin N. S. Interaction in Cu-In-Cr-Se(Te) Systems in the Region of Existence of Magnetic Phases with High Temperatures of Magnetic Ordering (Tc). Dis. for Cand. Sci. (Chem.). RAS, N.S. Kurnakov Institute of General and Inorganic Chemistry. 2002. 121 p.

16. Aliev I. I., Ismailova S. Sh., Guseynova Sh. A., Akhmedova D. A. Phase Equilibria in the As₂Te₃-Cu₂Cr₄Te₇ System Eurasian Union of Scientists 2021. 6/67. No. 1. pp. 14-17. DOI: 10.31618/ESU.2413-9335.2021.1.87.1389

17. Ismayilova S.Sh., Aliyev I.I., Ahmedova C.A., Alverdiyeva F.H., Gurbanov G.B. Study of glass formation in the As₂S₃-Cu₂Cr₄Te₇ system // Ganja State University International Scientific Conference. Actual problems of modern natural and economic sciences. Ganja. 2021. May 6-7. P.3-9.

18. . Khvorestenko A.S. Arsenic chalcogenides. Review from the series "Physical and chemical properties of solids". - Moscow, 1972. 92 p.

HISTORICAL SCIENCES

THE SIMILARITIES AND DIFFERENCES BETWEEN THE REVOLUTIONARY LINES OF THE COMMUNIST INTERNATIONAL AND HO CHI MINH

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Abstract

In the course of seeking a path to national salvation for Vietnam, Hồ Chí Minh engaged with and assimilated various revolutionary ideologies from around the world, most notably Marxism–Leninism and the revolutionary line of the Communist International (Comintern). However, Hồ Chí Minh did not adopt these doctrines mechanically. Instead, he creatively applied their core revolutionary principles to the specific historical and social conditions of Vietnam. A comparative study of the revolutionary strategies of the Communist International and Hồ Chí Minh not only elucidates their shared objectives and methods of struggle but also highlights Hồ Chí Minh's strategic intellect and independent revolutionary thought, which played a decisive role in guiding Vietnam to success. This article delves into the similarities and differences between the two revolutionary paths, thereby underscoring Hồ Chí Minh's revolutionary leadership and strategic wisdom.

Keywords: the Communist International (Comintern), Ho Chi Minh, Revolutionary lines, Marxism–Leninism

1. Introduction

The Vietnamese revolution has undergone a long and arduous struggle for national independence and freedom, in which the influence of international revolutionary movements—especially the Communist International—played a significant role. Nevertheless, each revolutionary movement had its own unique characteristics, shaped by the specific contexts and goals of individual nations. A prominent example of the connection between the international communist movement and the Vietnamese revolution is Hồ Chí Minh—an eminent leader who inherited and further developed revolutionary ideals from abroad into a path tailored to Vietnam's unique circumstances.

The similarities and differences between the revolutionary lines of the Communist International and Hồ Chí Minh are most clearly observed in their guiding principles, strategic orientations, and specific objectives. While the Communist International emphasized the unification of global revolutionary movements into an international proletarian front, Hồ Chí Minh focused on creatively adapting revolutionary theory to Vietnam's national context, constructing a revolutionary path grounded in local realities. This article aims to analyze the key similarities and distinctions between the revolutionary strategies of the Communist International and Hồ Chí Minh, thereby shedding light on both the influence of international communism on Vietnam's revolution and Hồ Chí Minh's innovations in applying revolutionary theory to Vietnamese conditions.

2. The Emergence of the Communist International and Hồ Chí Minh's Journey to National Salvation

2.1. The Birth and Formation of the Communist International's Revolutionary Line

The Communist International (Comintern) was an international organization of Communist Parties, established with the aim of promoting global proletarian revolution and fostering solidarity among revolutionary movements worldwide. Its creation was closely linked to several pivotal events in early twentieth-century history, particularly the October Revolution of 1917, the success of the Bolshevik Party under Vladimir Lenin's leadership, and the subsequent expansion of the international workers' movement.

Historical origins and context: Following the triumph of the October Revolution in 1917, Soviet Russia became the first nation to establish a proletarian government. This victory served as a powerful source of inspiration for revolutionary movements and Communist parties around the world, especially those fighting for national liberation in colonial territories. By the early twentieth century, communists in many countries had come to realize the need for an international organization to support and coordinate revolutionary efforts in the colonies. Although earlier international organizations—such as the First and Second Internationals founded by Karl Marx and Friedrich Engels—had played important roles in shaping workers' movements, none had successfully organized a coherent global revolutionary front. The Comintern was founded to fill this void.

Founding declaration: On March 2, 1919, in Moscow, the Communist International was formally established during a congress of Communist delegates from various countries. The Bolshevik leadership—particularly Lenin and the Communist Party of Russia—played a central role in this process. The primary objective of the Communist International was to unite communist parties across the world, organize revolutionary movements, and secure proletarian leadership in colonial nations in the struggle against imperialism and

capitalist forces. The organization did not limit itself to revolutionary efforts in Europe but sought to extend its influence to colonies and oppressed regions in Asia, Africa, and Latin America.

Program and objectives: The Comintern proposed a program of action aimed at fostering a global revolutionary movement, advancing class struggle, and establishing the dictatorship of the proletariat. Its key objectives included: disseminating Marxist–Leninist theory—particularly its emphasis on proletarian revolution and proletarian dictatorship; intensifying revolutionary movements in various countries—particularly those with a strong and active working-class movement—in order to fight against imperialism, capitalism, and counter-revolutionary forces; and organizing international workers’ associations, conferences, and coordinated uprisings across different countries.

Role and influence: The Comintern exerted a profound influence on communist movements worldwide throughout the interwar period, between the First and Second World Wars. Nevertheless, it was often criticized for excessive interference in the internal affairs of national Communist Parties, which led to fragmentation within revolutionary movements and reduced their autonomy. The Comintern also faced challenges in maintaining strategic unity due to differing conditions and revolutionary approaches among member countries.

Dissolution and long-term legacy: Although the Comintern was dissolved in 1943 amidst the global upheaval of World War II, its establishment and activities left a profound legacy on the history of international communist and workers’ movements. Communist Parties around the world continued to draw on the theoretical foundations and revolutionary strategies promoted by the Comintern well into the twentieth century. More than a political organization, the Comintern symbolized international solidarity among the working class and global revolutionary forces, encompassing national liberation and people’s democratic revolutions. Its emergence marked a significant turning point in the history of the world revolutionary movement, representing what Nguyễn Thế Lực described as “a tremendous victory of Marxism–Leninism over opportunism and revisionism” (Nguyễn Thế Lực 2006, p. 28). Despite its relatively short existence, the legacy of the Comintern continued to shape communist and revolutionary movements in numerous countries for decades to come.

2.2. The Formation of Hồ Chí Minh’s Revolutionary Line

In 1858, French colonial forces invaded Vietnam, sparking a series of patriotic movements aimed at reclaiming national independence. Figures such as Trương Định, Nguyễn Trung Trực, Trần Tấn, Đặng Như Mai, Nguyễn Xuân Ôn, Phan Đình Phùng, Nguyễn Thiện Thuật, and Nguyễn Quang Bích emerged as prominent leaders in anti-colonial resistance. However, these movements largely failed due to the absence of a correct revolutionary line. Rooted in feudal ideology, they were often characterized by loyalty to the monarchy, intense nationalism, and a spirit of vengeance, rather than clear strategic direction.

Entering the early 20th century, patriotic movements in Vietnam began adopting bourgeois ideological elements. Exemplary efforts include the Đông Du Movement led by Phan Bội Châu, the Đông Kinh Nghĩa Thục (Tonkin Free School), the Duy Tân (Modernization) movement, and the Việt Nam Quang Phục Hội (Vietnam Restoration League), with key figures such as Phan Bội Châu, Trần Quý Cáp, Nguyễn Hưởng, Phan Châu Trinh, Huỳnh Thúc Kháng, Ngô Đức Kế, Đặng Nguyên Cánh and etc.... Compared to their feudal predecessors, these movements showed improvement in organization and scale, and “had a revitalizing effect on Vietnam’s patriotic spirit” (Trịnh Nhu, Vũ Dương Ninh 1996, p. 20). However, they also failed to achieve the ultimate goal of national independence. These successive failures reflected a profound crisis in Vietnamese society at the time—specifically, a deadlock regarding the path to national salvation and a lack of a coherent revolutionary strategy.

Hồ Chí Minh (1890–1969), born in Nghệ An Province—a region renowned for its revolutionary tradition and resistance against foreign invasion—emerged within this historical context. Inheriting the patriotic legacy of figures such as Phan Bội Châu, Phan Châu Trinh, and Nguyễn Thái Học, etc., Hồ Chí Minh chose a different path. Rather than following in their footsteps, he sought to understand the sources of successful bourgeois revolutions in the West—such as the English, French, and American Revolutions. As he declared: “I went abroad to see France and other countries. After observing how they did things, I would return to help my fellow countrymen” (Trần Dân Tiên 1986, p. 14).

In 1911, Hồ Chí Minh left Vietnam from the Nhà Rồng Wharf in Saigon and traveled to France. In 1912, he arrived in the United States and stayed until mid-1913 before moving to the United Kingdom, where he remained until 1917. Toward the end of 1917, he returned to France (Song Thành 2006a, p. 54). In France, the first major turning point in Nguyễn Tất Thành’s political career occurred in 1919, when he, along with Phan Văn Trường and Phan Chu Trinh, drafted and submitted a petition to the Versailles Conference under the pseudonym Nguyễn Ái Quốc. The petition, consisting of eight points, was titled *The Claims of the Annamite People*. Upon its submission, the petition was published in full by *L’Humanité* and *Le Populaire*, the official newspapers of the French Socialist Party. Although these demands were ignored by U.S. President Woodrow Wilson, they generated significant attention in France and internationally. French newspapers such as *L’Humanité* and *Le Populaire* published the full text, and the initiative profoundly influenced Vietnamese public consciousness. As noted by Song Thành, “a courageous Vietnamese, under the name Nguyễn Ái Quốc, for the first time dared to bring the political issue of Vietnam to the international stage, demanding fundamental, legitimate rights for the nation—a watershed moment in Vietnam’s journey toward independence” (Song Thành 2006a, p. 66).

The spirit of this *Petition* provided further impetus for Nguyễn Ái Quốc’s political activism in France during this period, culminating in his decision to join the

French Socialist Party. On August 2, 1919, he published his first article in *L'Humanité*, titled "The Question of the Indigenous People," which echoed the core themes of the Eight Demands and denounced France's brutal colonial policies in Indochina. Then, on June 16–17, Hồ Chí Minh encountered Lenin's Preliminary Theses on the National and Colonial Questions published in *L'Humanité*. Speaking about his emotions and realizations after reading V.I. Lenin's *Theses*, Ho Chi Minh wrote: "In those theses, there were many difficult political terms. But I read them again and again until I grasped the essentials. Lenin's theses moved me deeply, enlightened me, and filled me with confidence. I was so happy I cried. Sitting alone in my room, I exclaimed as if addressing a crowd: '*Dear oppressed compatriots! This is what we need; this is the path to our liberation!*' From then on, I had complete faith in Lenin, in the Third International" (Hồ Chí Minh 2011e, p. 562).

Alongside the event of reading V.I. Lenin's *Theses* (1920), Nguyễn Ái Quốc (Ho Chi Minh) voted in favor of the Third International (December 1920), participated in the 1st (1920) and 2nd (1922) Congresses of the French Communist Party, attended the First Congress of the Peasants' International (October 1923), the Fifth Congress of the Communist International (June 17 – July 8, 1924), authored *The Judgment of French Colonialism* (1925), *The Revolutionary Path* (*Đường Cách Mệnh*, 1927), and wrote the *Political Thesis* (1930). These key events laid the essential ideological, theoretical, and organizational foundations for the establishment of the Communist Party of Vietnam in 1930. Based on his revolutionary praxis and the ideas expressed in his works during this period, it can be affirmed that "Ho Chi Minh's thought on the revolutionary path of Vietnam had been fundamentally formed" (Võ Nguyên Giáp, 2003, p. 30). From that point onward, Ho Chi Minh came to be regarded as "a model communist and internationalist fighter" (Marx–Lenin Institute, 1990, p. 46).

3. The Similarities between the Revolutionary Lines of the Communist International and Hồ Chí Minh

Through our research, we have identified several key similarities between the revolutionary strategies of the Communist International (Comintern) and Hồ Chí Minh:

First, in terms of theoretical foundations, both the Communist International and Ho Chi Minh's thought were grounded in Marxist–Leninist theory, which posits that "*class struggle is the driving force of historical development*" (Marx & Engels, 1995, p. 199), and that the proletarian revolution is the means of emancipation for both the class and humanity as a whole—a revolution that Marx and Engels described as "*a universal social revolution*" (Marx & Engels, 1995, p. 338). The crucial point of convergence between the theoretical frameworks of the Communist International and Ho Chi Minh's ideology lies in their shared inheritance and further development of the fundamental principles of Marxism–Leninism—particularly the view that "*class struggle is the driving force behind the development of human social history*" (Marx & Engels,

1995, p. 199), and that the proletarian revolution is the only path to liberation from oppression and injustice. This solid theoretical foundation served as the basis for the entire political platform, strategic orientation, and methods of action of both the Communist International and Ho Chi Minh's revolutionary line.

Marxism–Leninism posits that throughout human history, society has evolved through struggles between progressive productive forces and obsolete, reactionary ruling classes. In capitalist societies, the working class represents the advanced productive force, yet suffers systemic exploitation by the bourgeoisie. Hence, proletarian revolution is seen as a necessary means to abolish class oppression and establish a new social order in which laboring people hold power. Under Lenin's leadership, the Communist International spread this theory globally, with a particular emphasis on exporting revolution to colonized and semi-colonized nations—regions subjected to dual oppression: by foreign imperialism and by local feudal systems. Thus, the Communist International advocated for national liberation revolutions led by the proletariat as an integral component of the global proletarian revolution. This achievement affirms that "the great merit of V.I. Lenin and the Communist International lies in the fact that, for the first time in the history of the struggle against capitalism, they were able to unite national liberation movements into a single, cohesive force—recognizing them as an integral part of the structure of the world revolution" (Nguyễn Thành, 1987, p. 103).

Hồ Chí Minh systematically studied Marxism–Leninism and applied its principles—especially those of class struggle and proletarian revolution—in a flexible and creative manner suited to Vietnam's specific conditions. He identified the fundamental contradiction in early 20th-century Vietnamese society as that between the Vietnamese people and French colonialism. Yet he did not isolate national liberation from class struggle. Instead, he viewed them as dialectically linked. For Hồ Chí Minh, true national liberation must entail social liberation and human liberation—objectives achievable only through proletarian revolution. He clearly affirmed the central role of the working class and the Communist Party as the only force capable of leading the revolution to final victory, famously declaring: "To save the country and liberate the nation, there is no other way than the proletarian revolution" (Hồ Chí Minh, 2011, a, 1, p. 30), and: "Only a party that creatively applies Marxism–Leninism to its country's specific conditions can lead the national liberation revolution to victory and the socialist revolution to success" (Hồ Chí Minh, 2011, f, 15, p. 391). This perspective aligned closely with the revolutionary direction advocated by the Communist International.

Both also emphasized the pivotal role of revolutionary theory in guiding social transformation. Marx noted, "Theory also becomes a material force once it grips the masses" (Marx & Engels, 1995, a, 1, p. 580). Similarly, Hồ Chí Minh asserted, "Without revolutionary theory, there can be no revolutionary movement" (Hồ Chí Minh, 2011, d, 11, p. 93). For both, theory was not mere abstraction but a strategic tool for action—a compass for decision-making. Therefore, both Hồ Chí

Minh and the Comintern prioritized the building of a new type of party, cadre training, and political education for the masses as indispensable elements of revolution.

From this shared theoretical foundation, both Hồ Chí Minh and the Communist International understood class struggle as a fundamental driving force of social progress and proletarian revolution as the necessary path toward national liberation and the eradication of injustice. This ideological congruence provided a solid theoretical basis for linking the Vietnamese revolution to the broader international revolutionary movement, and also served as a bulwark “against distortions of Marxism–Leninism from both the left and the right” (Viện Quan hệ Quốc tế, 2005, , p. 139). Later, the dissolution of the Comintern would “cause fragmentation within the socialist bloc, weaken global revolutionary forces, and complicate international relations to the detriment of national liberation struggles—Vietnam’s included” (Trần Minh Trường, 2005, , p. 21).

Second, regarding objectives: Both Hồ Chí Minh and the Communist International shared a vision of overthrowing colonial and feudal regimes to establish a socialist society. They agreed that the ultimate goal of revolution was not merely regime change, but the complete emancipation of humanity from oppression and exploitation. Their shared vision sought to build a just, egalitarian, and humane society—ushering humanity from the “realm of necessity” into the “realm of freedom,” where “the free development of each is the condition for the free development of all” (Marx & Engels, 1995, c, 39, p. 258). Accordingly, both revolutionary paths prioritized the struggle against colonialism, imperialism, and other forces obstructing national and human development. Their central slogan—“struggle for peace”—united democratic forces willing to join the movement against imperialist war (Viện Quan hệ Quốc tế, 2005, , p. 137).

Founded in 1919 under Lenin’s leadership, the Communist International called for global proletarian revolution. This was reflected in Lenin’s appeal: “Proletarians of all countries and oppressed nations, unite!” (Lenin, 1981). A key priority was the liberation of colonized peoples from imperialist oppression and support for revolutionary uprisings in the East. Thus, “the colonial question became a focal point in the Comintern’s agenda” (Hùng Thắng & Nguyễn Thành, 2005, , p. 33). In its manifesto, the Comintern viewed national independence as a precondition for the establishment of proletarian rule and the eventual construction of a classless, communist society.

For Hồ Chí Minh, particularly after adopting Marxism–Leninism and engaging with the Comintern, national independence was a vital, non-negotiable prerequisite for any further revolutionary goals. He argued that without national independence, no ideology—not even communism—could be realized. Thus, Hồ Chí Minh emphasized that the foremost task of the revolution was national liberation, to be followed by social reform and the building of socialism. This position carried “a truly global revolutionary significance” (Phạm Xanh, 2009, , p. 29). In his Brief Political Strategy for the Communist Party of Vietnam, he wrote:

“While promoting the slogan of Annam’s independence, we must simultaneously propagate and carry out international solidarity with the oppressed nations and the global proletariat” (Đảng Cộng sản Việt Nam, 1999, , p. 5).

The similarity between these two revolutionary lines is further reflected in the shared perception that revolution is not merely a political event, but a long-term process requiring the integration of political, ideological, and economic struggles. Both the Communist International and Ho Chi Minh emphasized that revolution must be rooted in the active participation of the working masses—who constitute the principal force and fundamental driver in overthrowing exploitative and oppressive powers.

In addition, the shared revolutionary objective of both ideologies is evident in their vision of a universal society—a world of equality, freedom, and peace, without war, class divisions, or racial discrimination. Ho Chi Minh once asserted: “Nothing is more precious than independence and freedom!” (Ho Chi Minh, 2011c, Vol. 5, p. 1), and further emphasized: “Only communism can save humanity and bring to all people—regardless of race or origin—freedom, equality, fraternity, solidarity, prosperity on this earth, jobs for all and by all, joy, peace, and happiness; in short, a true world republic, eliminating capitalist boundaries that have until now stood as long walls separating workers from understanding and loving one another” (Ho Chi Minh, 2011a, Vol. 1, p. 496). These ideals were entirely consistent with the revolutionary platform of the Communist International.

Thus, the similarity between the Communist International and Ho Chi Minh regarding revolutionary goals was not merely a theoretical convergence, but a “practical unity forged through struggle” (Phan Ngọc Lien, 1995, p. 84). Both identified national liberation as the central mission in colonial contexts and saw it as the breakthrough point toward constructing a new society. These ideals inspired the revolutionary spirit of millions of Vietnamese patriots, creating a broad-based liberation movement throughout the 20th century and leaving a profound mark on human history. Ho Chi Minh, indeed, “placed the Vietnamese revolution within a global context” (Nguyen Phuc Luan, 1999, p. 52).

Third, regarding methods: relying on the masses, especially the worker–peasant alliance, to carry out armed struggle

A crucial and prominent similarity between the revolutionary methods of the Communist International and Hồ Chí Minh lies in their shared emphasis on mass mobilization—particularly of the worker–peasant alliance—as the foundational force in conducting armed struggle. Rooted in the Marxist–Leninist principle that “revolution is the work of the awakened and organized masses, and armed uprising is the highest form of mass movement” (Phạm Quốc Thành, 2007, , p. 128), both lines of thought advanced a strategy wherein the revolutionary process is carried out by the people themselves. This viewpoint is not merely a strategic directive but also a fundamental and immutable principle in the course of carrying out the proletarian revolution.

According to Marxism–Leninism, human history is a history of class struggle. In capitalist societies, the working class is the truly revolutionary class, and the one capable of initiating the most thorough transformation (Phạm Ngọc Dũng, 2007, , p. 17). The Communist International inherited and expanded upon this concept, asserting that successful proletarian revolution must be led by the Communist Party and executed by the masses—mainly workers and peasants. For this reason, every revolutionary movement guided or supported by the Comintern focused on organizing, educating, and mobilizing the masses as the subjects—not just the objects—of revolution. As Phan Ngọc Liên and Trịnh Vương Hồng (2001, p. 166) observed: “The global revolutionary movement advanced thanks to the guidance of the Communist International.”

The Communist International not only encouraged peaceful political struggles but also regarded armed struggle as a necessary and inevitable means under specific circumstances. The October Revolution of 1917 became the archetype of a successful proletarian revolution—organized, led, and carried out by the working class through resolute, armed resistance against the old ruling order.

Hồ Chí Minh absorbed this perspective early in his revolutionary journey. He understood that Vietnam’s independence could not be granted by imperial powers or restored by feudal elites. Instead, liberation would require the mobilization of “the strength of the people” (Phạm Hồng Chương, 2003, , p. 191)—those who had the most direct and profound stake in the success of national liberation. This ideology was clearly articulated by Ho Chi Minh in his official documents, writings, speeches, and most notably through his efforts in building revolutionary forces in Vietnam. Hồ Chí Minh consistently emphasized the decisive role of the working class as the vanguard of the revolution, while also recognizing the vital contributions of the peasantry, which made up the majority of Vietnam’s population.

As early as 1925, when organizing the Vietnam Revolutionary Youth Association, Hồ Chí Minh prioritized the recruitment and training of cadres from the working class and peasantry. He sought to disseminate revolutionary theory among the masses, awaken patriotic consciousness, and inspire a readiness to resist colonial domination.

In Hồ Chí Minh’s view, political and armed struggle were not mutually exclusive; they were complementary. Depending on the historical stage and material conditions, one could take precedence over the other. However, when the revolutionary moment arrived, the people had to be prepared to seize power through armed insurrection. As he asserted, “Political power does not come by itself; it must be seized through struggle and the sacrifice of the people.” This was most clearly demonstrated during the August Revolution of 1945, when the unified strength of the entire nation, organized and led by the Communist Party of Vietnam, rose up in unison to seize power from the colonialists and feudalists.

Both Hồ Chí Minh and the Communist International understood that revolution could not rely on a

small elite or intellectual class alone. Instead, revolution must be the collective uprising of the working masses. Revolutionary methodology is not merely theoretical; it must be transformed into practical action—where every citizen becomes a revolutionary fighter.. The masses were not simply recipients of propaganda but were, in fact, the principal agents of change. This methodological similarity ensured that the Vietnamese revolution was not merely a national movement but one deeply intertwined with the global revolutionary wave. The fusion of national and class struggle, of theory and mass mobilization, of political and armed action, became a hallmark of both Hồ Chí Minh’s and the Comintern’s revolutionary strategy.

Ultimately, both revolutionary lines affirmed that the key to success lay in the decisive role of the masses—especially the worker–peasant alliance—in initiating and sustaining armed struggle to overthrow oppressive regimes and establish a government of the people. This approach represented the synthesis of revolutionary theory and practical action, of internationalist ideals and national identity, giving rise to a powerful and enduring force for national liberation and socialist construction.

Fourth, in terms of revolutionary organization: both emphasized the leading role of the Communist Party.

A fundamental similarity between the revolutionary strategies of the Communist International and Hồ Chí Minh lies in their unequivocal affirmation of the essential and irreplaceable leadership role of the Communist Party in the revolutionary process. Both frameworks are grounded in the Marxist–Leninist conviction that only a political party representing the working class, possessing a tightly organized structure, a scientifically grounded ideology, and deep roots among the masses, can successfully guide the revolution to its final triumph.

The Communist International was established with the mission of uniting Communist Parties around the world into a single, unified international revolutionary movement. Within its ideological framework, the Comintern consistently emphasized the central role of the Communist Party as the primary instrument for organizing, directing, and sustaining revolutionary activity. Its resolutions clearly articulated that only a Communist Party, grounded in Marxist–Leninist principles, could initiate revolution, guide it toward victory, and safeguard its achievements. The Party was not only the core of leadership but also a symbol of unity in politics, ideology, and action.

Hồ Chí Minh, upon adopting these principles, did not replicate them mechanically. Rather, he adapted them to Vietnam’s unique historical and social conditions. From the founding of the Vietnam Revolutionary Youth Association in 1925, he prioritized the political education and ethical training of a cadre force characterized by revolutionary integrity, ideological commitment, and deep knowledge of Marxism–Leninism. This preparation was intended to lay the foundation for establishing a new-type revolutionary party: the Communist Party of Vietnam. In his seminal work *Revolution*

tionary Path (1927), Hồ Chí Minh stressed the indispensable role of a revolutionary party, stating: “To carry out revolution, there must be a revolutionary party,” and that “the Party must firmly uphold the working-class stance, taking Marxism–Leninism as the compass for all its actions.” This viewpoint reflects a profound alignment with the Comintern’s position on the Communist Party as the sole force capable of organizing, leading, and defending the revolution.

Both Hồ Chí Minh and the Communist International viewed the Party’s leadership as not merely political, but also ideological and organizational. The Party was to serve as the guiding force of the working class, with strict discipline, clear revolutionary ideals, and a close relationship with the people. It could not function as a bureaucratic entity removed from reality; rather, it had to embody the will, aspirations, and interests of the working class and the broader laboring population.

Therefore, when the Communist Party of Vietnam was founded in 1930 under the leadership and guidance of Nguyễn Ái Quốc, one of its fundamental organizational principles was loyalty to Marxist–Leninist theory, the implementation of unified and centralized leadership, and the assurance of internal democratic principles. The Party’s leadership was comprehensive, encompassing political strategy, the organization of popular struggles, the building of mass fronts, and the launching of armed uprisings.

The Comintern likewise mandated that Communist Parties operate as vanguard forces, overcoming reformism, opportunism, and narrow nationalism. It envisioned these Parties as nuclei for mobilizing all authentic revolutionary forces. This perspective profoundly influenced Hồ Chí Minh’s thinking on party organization and development. He consistently regarded Party building as a central task throughout every stage of the revolutionary process, emphasizing that only a strong Party—grounded in sound theoretical foundations and closely connected to the people—could successfully lead the revolutionary cause.

Thus, both the Comintern and Hồ Chí Minh were united in their conception of the Communist Party as the highest form of revolutionary organization—the vanguard of the proletariat, the force that shapes and guides the revolutionary process. This convergence provided a durable theoretical and practical foundation for both the Vietnamese and international revolutionary movements.

4. The Differences between the Revolutionary Lines of the Communist International and Hồ Chí Minh

First, a fundamental difference lies in the interpretation and determination of the nature of revolution in the colonial context of Vietnam.

The Communist International, particularly in the early 20th century, primarily focused on fostering proletarian revolutions in advanced capitalist nations. It adopted the October Revolution in Russia as the paradigmatic model of socialist revolution and promoted a model centered on the class struggle between the proletariat and bourgeoisie within industrialized societies.

From this perspective, the Comintern emphasized that the proletarian revolution—led by the working class and aimed at overthrowing the capitalist regime—was the universal and inevitable path for all oppressed nations. Although the Comintern had issued resolutions on national liberation movements in colonial countries (such as at its Second Congress in 1920), the practical application of these ideas remained underdeveloped. In particular, the relationship between national liberation struggles and the socialist revolution was not fully clarified in theory or practice—especially in contexts as specific and complex as Vietnam’s.

In contrast, Hồ Chí Minh, drawing upon Vietnam’s unique realities as a colonized, semi-feudal nation—with a nascent proletariat and a predominantly peasant population—argued that the foremost and most urgent revolutionary task was national liberation. For him, social revolution was only possible after the nation achieved political independence. He asserted that, in the Vietnamese context, the national liberation struggle and the class struggle were closely connected; however, the class struggle could not be placed above the national struggle. National liberation was the immediate and decisive contradiction, and addressing it was a necessary precondition for any subsequent class-based transformation.

Thus, the revolution led by Hồ Chí Minh was defined as a national democratic people’s revolution—a transitional phase required to pave the way for the socialist revolution. He clearly stated that the first step was to gain national independence; only then could Vietnam proceed with comprehensive social reform along the path of socialism. This perspective demonstrated Hồ Chí Minh’s dialectical and creative application of Marxist–Leninist theory to Vietnam’s historical context.

For Hồ Chí Minh, the nature of revolution in Vietnam was not solely class-based; it was, above all, a national revolution aimed at liberating the people from colonial domination. It bore the characteristics of mass participation, national solidarity, and international alignment. This emphasis on national liberation, adapted to the colonial condition, represents a distinctive feature of Hồ Chí Minh’s revolutionary thought as compared to the general line of the Comintern.

From this foundational difference, Hồ Chí Minh advocated for a broad-based national alliance—uniting all patriotic forces regardless of class origin—so long as they shared the objective of resisting imperialism and achieving independence. This inclusive approach helped expand the national united front and mobilize the collective strength of the entire population in the liberation struggle.

Whereas the Comintern approached revolution primarily through a class-based lens, Hồ Chí Minh supplemented this with a national lens—placing the struggle for independence at the core, and only subsequently pursuing the socialist transformation. This strategic shift represented an original and contextually appropriate innovation that ultimately contributed to the success of the Vietnamese revolution.

Second, a notable difference lies in the approach to revolutionary alliances

A significant distinction between the Communist International and Hồ Chí Minh pertains to their respective views and strategies regarding the composition of revolutionary alliances. The Comintern, grounded in the Marxist–Leninist theoretical framework, held that the working class (proletariat) was the sole force capable of leading a successful revolution. Accordingly, it emphasized the formation of a proletarian-led alliance—primarily between workers and peasants—as the foundation for advancing the global proletarian revolution.

In its official documents and directives, the Comintern tended to discount or underestimate the role of social strata outside of the working class and peasantry, especially the petty bourgeoisie, intellectuals, small landlords, and even national bourgeois elements. These groups were often viewed with skepticism, as potential conduits for opportunism or deviation from proletarian principles. As such, the Comintern's directives generally discouraged broad-based alliances that included non-proletarian forces, for fear of diluting the class character of the revolution.

In contrast, Hồ Chí Minh, responding to the complex sociopolitical conditions in colonial Vietnam, adopted a much more pragmatic and inclusive approach. He understood that the Vietnamese revolution, first and foremost a national liberation movement, demanded the broadest possible unity of all patriotic forces, regardless of class background. This required overcoming rigid class distinctions to forge a unified front against the common enemy: colonial imperialism and feudalism.

Thus, Hồ Chí Minh advocated for a revolutionary alliance that extended beyond the working class and peasantry to include intellectuals, small landlords, national bourgeois elements, and other patriotic groups. His strategy was to unite all those who were willing to fight for independence, regardless of their class origins or ideological leanings. This approach was clearly articulated in the 1930 Political Thesis of the Communist Party of Vietnam, which stated: “We must establish contact with all oppressed peoples and exploited classes in order to jointly overthrow imperialism and feudalism.” This principle became foundational to Hồ Chí Minh's doctrine of building a National United Front—a broad political coalition that transcended class boundaries in pursuit of national independence. The Việt Minh Front, established in 1941, was the most prominent manifestation of this approach. It mobilized not only workers and peasants, but also students, intellectuals, merchants, and even progressive landlords—all united in the anti-colonial struggle. This mass-based, inclusive alliance proved decisive in the success of the August Revolution in 1945.

Hồ Chí Minh's initiative to broaden the great national unity bloc was not merely a tactical maneuver but a deeply strategic vision. He recognized that under the brutal repression of colonial rule, a successful revolution could not rely solely on one or two social classes. Instead, it was essential to mobilize all patriotic forces—including those not yet fully committed to socialism but willing to join the struggle for national in-

dependence. This inclusive approach reflected a pragmatic yet principled understanding of revolutionary dynamics in colonized societies.

This inclusive and flexible view of revolutionary alliances represents a clear departure from the more rigid class-centric orientation of the Comintern. Hồ Chí Minh's model emphasized unity over uniformity, and patriotism over class exclusivity, without abandoning the long-term socialist goal. His strategic innovation lay in recognizing that national liberation was the common denominator that could bind diverse social forces into a single revolutionary movement.

In this way, Hồ Chí Minh transformed the Marxist–Leninist concept of class alliances into a broader framework of national solidarity. His success in doing so illustrates not only his political pragmatism but also his capacity to adapt universal theories to specific historical and cultural contexts. This difference in approach proved to be a key factor in the widespread support and eventual triumph of the Vietnamese revolution.

Third, the difference in cultural and national approaches: the Comintern's class-oriented model versus Hồ Chí Minh's integration of national traditions and patriotism

A profound and strategically significant difference between the revolutionary lines of the Communist International and Hồ Chí Minh lies in their respective approaches to culture, national identity, and indigenous traditions. The Comintern, shaped by the context of industrialized Europe and a developed proletarian class, primarily emphasized a universal, class-based model of revolution grounded in Marxist–Leninist theory. This orientation led to a tendency to overlook or downplay the role of local cultures, historical specificities, and traditional values—particularly in colonized or semi-colonial societies. Consequently, the Comintern promoted a model of international revolution that prioritized ideological uniformity and attempted to replicate the experience of the October Revolution across vastly different national contexts. In doing so, it often failed to account for the distinct cultural and historical characteristics of societies like Vietnam, where social structures, values, and political consciousness differed significantly from those in Western Europe.

In contrast, Hồ Chí Minh early recognized that a successful revolution in Vietnam could not be achieved solely through abstract theoretical frameworks or externally imposed models. He understood that national culture—particularly the spirit of patriotism, traditions of solidarity, and moral principles such as gratitude and filial piety—constituted powerful sources for mobilizing popular support and sustaining revolutionary spirit. Rather than viewing culture as secondary or neutral, Hồ Chí Minh placed it at the center of revolutionary strategy. Therefore, while firmly adhering to Marxist–Leninist principles, Hồ Chí Minh applied them in a flexible and creative manner, adapting them to the specific historical and cultural conditions of the Vietnamese nation.

Hồ Chí Minh did not separate class struggle from the broader context of national liberation, which was

the most urgent demand of the Vietnamese people under colonial domination. Therefore, his revolutionary slogan was not merely to overthrow the domestic ruling class, but to "Expel the French colonizers – achieve national independence." This marked a fundamental shift in revolutionary thought—from a purely class-based theoretical framework to a synthesis of class and national struggle. This perspective is clearly articulated in seminal works such as *The Colonial Question* and *The Revolutionary Path*, where Hồ Chí Minh asserted: "To save the nation and liberate the people, there is no other path than the proletarian revolution" (Hồ Chí Minh 2011e, 30).

Thus, he did not isolate class struggle from national liberation, nor did he see Marxism–Leninism as incompatible with indigenous values. Instead, he developed a synthesis in which revolutionary theory was adapted to resonate with the lived experience and moral values of the Vietnamese people. Core cultural principles such as patriotism, solidarity, "drinking water, remember the source" (a Vietnamese idiom for gratitude), and respect for tradition became integral to the revolutionary message.

Hồ Chí Minh's slogans and propaganda reflected this cultural sensitivity. Rather than using abstract class terminology, he invoked familiar moral and historical narratives that appealed to peasants, intellectuals, and workers alike. His calls to "resist the French to save the country" or "nothing is more precious than independence and freedom" reflected both revolutionary purpose and cultural continuity. This was a decisive break from the Comintern's abstract and often Eurocentric rhetoric.

Such cultural integration was also evident in Hồ Chí Minh's emphasis on preserving and promoting Vietnamese identity within the revolution. He argued that "Culture lights the path for the nation" (Hồ Chí Minh, 2011), insisting that cultural development was inseparable from revolutionary struggle. As a result, revolutionary efforts were accompanied by campaigns to preserve the Vietnamese language, uphold traditional customs, and promote patriotic education. Even in his personal conduct, Hồ Chí Minh exemplified cultural modesty, simplicity, and closeness to the people—values deeply ingrained in Vietnamese social norms. In organizing the revolutionary movement, Hồ Chí Minh also encouraged cadres to maintain a simple lifestyle and remain close to the people, reflecting the spirit of "nationalizing" the revolution.

This culturally grounded approach enabled Hồ Chí Minh to translate Marxist–Leninist ideology into a language accessible to the masses, thereby fostering broad-based support for the revolutionary cause. The result was not a diluted form of Marxism, but a culturally enriched and politically effective application of it. By "nationalizing" revolutionary theory, Hồ Chí Minh succeeded in building a movement that was both ideologically coherent and socially resonant. Hồ Chí Minh's principle of "taking the people as the root" was, in essence, a vivid manifestation of his assimilation of Marxism–Leninism through the cultural and national lens of Vietnam.

In contrast, the Comintern's relative neglect of cultural factors limited its ability to adapt revolutionary theory to diverse colonial contexts. Its rigid class-centered framework often failed to inspire or mobilize populations with strong national and cultural identities. Hồ Chí Minh's success in Vietnam underscores the necessity of blending universal theory with national particularity—demonstrating that cultural insight is not a supplement to revolution, but one of its essential pillars.

Thus, while the Comintern focused primarily on class ideology and internationalism, Hồ Chí Minh offered a revolutionary model that synthesized socialism with patriotism, international solidarity with cultural heritage, and class struggle with national pride. This synthesis not only distinguished his revolutionary line but also helped ensure its legitimacy, popularity, and ultimate success in the Vietnamese context.

Fourth, differences in methods of struggle: the Comintern's emphasis on class-based violent revolution versus Hồ Chí Minh's flexible combination of political, military, diplomatic, and cultural means

A prominent difference between the revolutionary lines of the Communist International and Hồ Chí Minh lies in their respective approaches to the methods of struggle. While the Comintern prioritized radical and often violent class struggle as the principal vehicle for revolution, Hồ Chí Minh adopted a more pragmatic, flexible approach—emphasizing the strategic combination of political mobilization, armed resistance, diplomacy, and ideological persuasion, with a consistent emphasis on national unity and patriotism.

The Comintern, grounded in the revolutionary experience of Soviet Russia and the Marxist–Leninist emphasis on the "dictatorship of the proletariat," often regarded violent class confrontation as both necessary and inevitable. The October Revolution had demonstrated the viability of seizing state power through armed uprising, and the Comintern sought to universalize this method as the essential model for global revolution. Within this framework, violent overthrow of the bourgeoisie and the establishment of proletarian dictatorship were considered indispensable steps toward socialism.

This rigid adherence to armed class struggle often resulted in a one-size-fits-all approach, with insufficient adaptation to the specific socio-political realities of colonized nations like Vietnam. The Comintern's methods prioritized the internal class contradiction over other strategic considerations, including national identity, historical conditions, and geopolitical balance.

In contrast, Although Hồ Chí Minh adopted the spirit and theoretical foundation of Marxism–Leninism and affirmed the necessity of class struggle, he did not absolutize this form of struggle. Instead, he advocated for the combination of multiple methods—political, diplomatic, armed, and ideological-cultural struggles—executed with a high degree of flexibility and pragmatism. In his thought, class struggle was always subordinated to the overarching goal of national independence. Therefore, in specific historical contexts, expanding the national united front and mobilizing all patriotic

forces—including landlords and national bourgeois elements—was not only necessary but a strategic imperative.

He stated unequivocally: “National liberation takes precedence above all else” (Hồ Chí Minh, 2011, b, 3, p. 230). This principle guided his decision to prioritize the unification of all patriotic forces, including elements not traditionally aligned with the proletariat. During the August Revolution of 1945, he spearheaded the Việt Minh Front, which welcomed all social classes and political tendencies into the anti-colonial struggle. His strategy was not rooted in ideological rigidity, but in an acute understanding of national urgency and political timing.

Moreover, Hồ Chí Minh consistently advocated for the coordination of armed struggle with political activism and diplomatic engagement. In the resistance wars against both France and the United States, he combined guerrilla warfare with international diplomacy and ideological education. He sought international solidarity, lobbied for recognition at global forums, and emphasized public diplomacy to expose the crimes of imperialism and win support from progressive forces abroad.

This flexibility was not opportunistic; it was a strategic application of Marxist–Leninist principles in light of Vietnam’s colonial and semi-feudal reality. While the Comintern often advanced a monolithic model of revolution, Hồ Chí Minh adjusted the tactical balance according to the objective and subjective conditions of struggle.

He also placed strong emphasis on the role of ideas and morality in revolutionary practice. For Hồ Chí Minh, a successful revolution required not only arms and organization but also ethical conviction, national spirit, and intellectual clarity. Revolutionary struggle had to embody the people’s deepest aspirations and reflect their cultural values.

In essence, whereas the Communist International emphasized direct and violent confrontation with the ruling class as the principal method of revolution, Hồ Chí Minh embraced a strategy of integration—blending armed resistance with diplomacy, ideology with culture, and political struggle with popular mobilization. He elevated national unity above class exclusivity and subordinated theoretical orthodoxy to practical effectiveness.

This difference in method underscores the broader distinction in revolutionary vision: the Comintern’s approach was marked by ideological absolutism and doctrinal uniformity, while Hồ Chí Minh’s strategy was rooted in dialectical reasoning, political flexibility, and a profound understanding of Vietnam’s national reality. It was this adaptive and people-centered method that enabled the Vietnamese revolution to secure decisive victories in the mid-twentieth century.

Conclusion

Hồ Chí Minh adopted Marxism–Leninism as introduced through the Communist International, but applied it with flexibility and creativity, in accordance with the concrete conditions of Vietnam. While profoundly influenced by international revolutionary theory, he did not mechanically follow the models of other

countries. Instead, Hồ Chí Minh adapted core revolutionary principles to suit the particular historical, cultural, and social context of Vietnam. His revolutionary thinking and praxis reflected independent judgment, a sharp sense of realism, and a firm prioritization of national interests.

Hồ Chí Minh’s approach placed national liberation at the forefront, considering it the prerequisite for subsequent social transformation. For him, freedom from colonial domination was the indispensable first step, without which any aspiration toward socialism would be unattainable. Therefore, he strategically emphasized the mobilization of all patriotic forces, the unification of the national front, and the deployment of a multi-pronged revolutionary strategy—including armed struggle, political advocacy, diplomacy, and ideological education.

In doing so, Hồ Chí Minh demonstrated a capacity not only to absorb Marxist–Leninist theory but to master and transform it—shaping a revolutionary path that was distinctly Vietnamese and broadly effective. His methods revealed an astute ability to reconcile the universal with the particular: applying global theory in local practice, without sacrificing the foundational goals of socialism and human emancipation.

His flexibility in combining different forms of struggle, especially his integration of military, political, and diplomatic efforts with cultural and moral elements, proved crucial in ensuring the success of the Vietnamese revolution. Rather than isolating the working class as the sole revolutionary subject, he united all oppressed and patriotic forces, fostering a broad coalition that made possible victories such as the August Revolution and the subsequent wars for national independence.

This success is not only a testament to Hồ Chí Minh’s strategic wisdom and ideological clarity but also serves as a powerful example of how revolutionary theory must be rooted in national conditions and adapted to the lived realities of a people. It affirms that revolutionary leadership requires not just ideological commitment, but the courage to think independently, to innovate in practice, and to serve the people with deep empathy and unwavering dedication.

In sum, Hồ Chí Minh brought forth a new current of revolutionary thought—independent, reality-driven, and deeply humanist. His legacy demonstrates the ability to master revolutionary theory not by imitating models, but by applying its principles in ways that are responsive to time, place, and people. Under his leadership, the Vietnamese revolution achieved monumental victories, laying the groundwork for national independence, freedom, and development. His path remains a compelling model of how revolutionary movements in the Global South can blend universal ideals with national identity, and theory with practice, to shape their own destinies.

References:

1. C. Marx, F. Engels. (1995a). *Collected Works*, Vol. 1. Hanoi: National Political Publishing House.
2. C. Marx, F. Engels. (1995b). *Collected Works*, Vol. 2. Hanoi: National Political Publishing House.

3. C. Marx, F. Engels. (1995c). *Collected Works*, Vol. 39. Hanoi: National Political Publishing House.
4. Dương Trung Quốc, Đào Hùng. (2005). “Hồ Chí Minh – An Embodiment of Peace Culture.” Hanoi: Saigon Culture Publishing House.
5. Communist Party of Vietnam. (1998). *Complete Party Documents*, Vol. 2. Hanoi: National Political Publishing House.
6. E. Copelev. (1985). *Comrade Hồ Chí Minh*. Hanoi: Youth Publishing House.
7. Hồ Chí Minh National Academy of Politics. (2005). *Textbook on the History of the Communist and International Workers’ Movement*. Hanoi: Theoretical Politics Publishing House.
8. Hồ Chí Minh. (2011a). *Collected Works*, Vol. 1. Hanoi: National Political Publishing House.
9. Hồ Chí Minh. (2011b). *Collected Works*, Vol. 3. Hanoi: National Political Publishing House.
10. Hồ Chí Minh. (2011c). *Collected Works*, Vol. 5. Hanoi: National Political Publishing House.
11. Hồ Chí Minh. (2011d). *Collected Works*, Vol. 11. Hanoi: National Political Publishing House.
12. Hồ Chí Minh. (2011e). *Collected Works*, Vol. 12. Hanoi: National Political Publishing House.
13. Hồ Chí Minh. (2011f). *Collected Works*, Vol. 15. Hanoi: National Political Publishing House.
14. Hùng Thắng, Nguyễn Thành. (2006). “President Hồ Chí Minh – Pioneer Fighter on the Front of National Liberation.” Hanoi: People’s Public Security Publishing House.
15. Hữu Ngọc. (2006). “A Sketch of French Cultural Portrait.” Hanoi: Literature Publishing House.
16. M. V. Iordan. (1985). “Proletarian Internationalism against Nationalism.” Hanoi: Theoretical Information Publishing House.
17. Nguyễn Khánh Bật. (2010). “Similarities and Differences in Revolutionary Views between Hồ Chí Minh and the Indochinese Communist International (1930–1941).” Hanoi: National Political Publishing House.
18. Nguyễn Phúc Luân. (1999). “President Hồ Chí Minh – A Great Thinker in Modern Vietnamese Diplomacy.” Hanoi: National Political Publishing House.
19. Nguyễn Thành. (1987). “The Communist International and the Colonial Question.” Hanoi: Marx–Lenin Schoolbook Publishing House.
20. Nguyễn Thế Lực. (2006). “Understanding the Subject of Communist, International Workers’ Movements and Global Geopolitics.” Hanoi: Theoretical Politics Publishing House.
21. Phạm Hồng Chương. (2003). “Hồ Chí Minh’s Thought on Basic Issues of the Vietnamese Revolution.” Hanoi: National Political Publishing House.
22. Phạm Ngọc Dũng. (2007). “Hồ Chí Minh’s Creative Application and Development of Marxism–Leninism on the Communist Party.” Hanoi: National Political Publishing House.
23. Phạm Quốc Thành. (2007). “Hồ Chí Minh’s Thought on National Liberation in the 1920s.” Hanoi: National Political Publishing House.
24. Phạm Xanh. (2001). “Nguyễn Ái Quốc and the Dissemination of Marxism–Leninism in Vietnam (1921–1930).” Hanoi: National Political Publishing House.
25. Phan Ngọc Liên, Trịnh Vương Hồng. (1994). “Hồ Chí Minh – International Revolutionary Fighter.” Hanoi: People’s Army Publishing House.
26. Phan Ngọc Liên. (1994). “Exploring Hồ Chí Minh’s Thought on International Issues.” Hanoi: National Political Publishing House.
27. Philippe Devillers. (2003). *Paris–Saigon–Hanoi*. Hanoi: Hồ Chí Minh City: General Publishing House.
28. Song Thành. (2006a). *Biography of Hồ Chí Minh*. Hanoi: Theoretical Politics Publishing House.
29. Song Thành. (2005b). *Hồ Chí Minh – A Brilliant Thinker*. Hanoi: Theoretical Politics Publishing House.
30. T. Lan. (2007). *Tales Along the Journey*. Hanoi: Hồ Chí Minh City: Youth Publishing House.
31. Trần Dân Tiên. (1986). *Stories of President Hồ’s Revolutionary Life*. Hanoi: Sự Thật (Truth) Publishing House.
32. Trần Minh Trường. (2005). “President Hồ Chí Minh’s Diplomatic Activities (1954–1969).” Hanoi: People’s Public Security Publishing House.
33. Trịnh Nhu, Vũ Dương Ninh. (1996). “On Hồ Chí Minh’s Path to National Liberation.” Hanoi: National Political Publishing House.
34. Trường Chinh. (1975). *The Vietnamese National Democratic People’s Revolution*, Vols. 1–2. Hanoi: Sự Thật (Truth) Publishing House.
35. V. I. Lenin. (1995). *Collected Works*, Vol. 29. Hanoi: National Political Publishing House.
36. Institute of Marxism–Leninism. (1990). *President Hồ Chí Minh – A Steadfast Fighter of the National Liberation and Communist Movements*. Hanoi: Theoretical Information Publishing House.
37. Institute for International Relations, Ministry of Foreign Affairs. (1990). *President Hồ Chí Minh and Diplomatic Work*. Hanoi: Sự Thật (Truth) Publishing House.
38. Võ Nguyên Giáp. (2003). “Hồ Chí Minh’s Thought and the Vietnamese Revolutionary Path.” Hanoi: National Political Publishing House.
39. Võ Văn Sung. (2010). “Reflections on the Hồ Chí Minh School of Diplomacy.” Hanoi: National Political Publishing House.
40. Vũ Dương Huân. (2005). “Hồ Chí Minh’s Thought on Diplomacy.” Hanoi: Youth Publishing House.
41. Vietnam National Commission for UNESCO. (1995). *Proceedings of the International Conference: President Hồ Chí Minh – National Liberation Hero, Great Man of Culture*. Hanoi: Social Sciences Publishing House.
42. William J. Duiker. (1995). *Hồ Chí Minh – A Life*. Hanoi: Hồ Chí Minh Institute and Leaders of the Party, Hồ Chí Minh National Academy of Politics.

MEDICAL SCIENCES

EFFECTIVE METHODS OF PREVENTING OBESITY IN CHILDREN AND ADOLESCENTS

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UŞAQ VƏ YENİYETMƏLƏRDƏ PIYLƏNMƏNİN PROFİLAKTİKASININ EFEKTİV ÜSULLARI

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Abstract

Examinations carried out in modern times confirm the widespread prevalence of obesity among adults, and also allow us to say that this disease is observed at an earlier age, among children and adolescents. The article presents information on the prevalence of obesity in children and adolescents in our modern life, and considers the issues of etiology, pathogenesis, prevention and treatment of the disease. In recent years, there has been a rapid increase in the number of children with overweight (obesity) problems all over the world. Thus, the trend of increasing the number of pathological cases of excess body weight has become one of the important problems of pediatrics. It is known that the role of both genetic and environmental factors and lifestyle is important in the development of obesity in children. All this shows the prevalence of obesity and the urgency of combating it. At the same time, unhealthy diet and lack of physical activity are the main determinants of the development of obesity. However, the complexity of the etiology and pathogenesis of the disease requires the development of evidence-based comprehensive measures involving not only medical science but also society and the family for its prevention and treatment. Therefore, further research is needed to effectively solve the problem of obesity in children and adolescents.

Xülasə

Müasir dövrdə aparılmış müayinələr piylənmənin böyüklər arasında geniş yayılmasını təsdiq etməklə yanaşı, həmçinin bu xəstəliyin daha erkən yaşlarda, uşaq və yeniyetmələr arasında da müşahidə edildiyini söyləməyə imkan verir. Tədqiqatda müasir həyatımızda uşaq və yeniyetmələrdə piylənmənin yayılması ilə bağlı məlumatlar təqdim olunur, xəstəliyin etiologiyası, patogenezi, profilaktikası və müalicəsi məsələlərinə baxılır. Son illərdə bütün dünyada artıq çəki (piylənmə) problemi olan uşaqların sayında sürətli artım müşahidə olunur. Belə ki, artıq bədən çəkisinin patoloji hallar sayının artma tendensiyası pediatriyanın mühüm problemlərindən birinə çevrilmişdir. Məlumdur ki, uşaqlarda piylənmənin inkişafında həm genetik, həm də mühit faktorlarının, həyat tərzinin rolu əhəmiyyətlidir. Bütün bunlar piylənmənin geniş yayılmasını və onunla mübarizənin aktuallığını göstərir. Eyni zamanda, qeyri-sağlam qidalanma və fiziki fəaliyyətin olmaması piylənmənin inkişafının əsas müəyyənədiciləridir. Bununla belə, xəstəliyin etiologiyası və patogenezinin mürəkkəbliyi onun qarşısının alınması və müalicəsi üçün tək tibb elmini deyil, həm də cəmiyyəti və ailəni cəlb etməklə sübuta əsaslanan kompleks tədbirlərin işlənilib hazırlanmasını tələb edir. Buna görə də uşaq və yeniyetmələrdə piylənmə problemini effektiv üsullarla həll etmək üçün əlavə tədqiqatlara ehtiyac vardır.

Keywords: overweight (obesity), children, adolescents, prevalence, risk factors, etiology, prevention and treatment.

Açar sözlər: izafi bədən çəkisi (piylənmə), uşaqlar, yeniyetmələr, yayılma, risk faktorları, etiologiya, profilaktika və müalicə.

Giriş. Ümumdünya Səhiyyə Təşkilatı piylənməni son illərdə əhəmiyyətli dərəcədə "cavanlaşmış" bəşəriyyətin "qlobal epidemiyası" elan etdi. Piylənmə hal-hazırda insan ömrünü qısaldan və keyfiyyətini aşağı salan bir sıra xəstəliklərin inkişafı ilə əlaqəli

polietoloji, xroniki, təkrarlanan xəstəlik hesab olunur. Ümumdünya Səhiyyə Təşkilatının məlumatına görə, artıq çəki (piylənmə) 2-ci tip şəkərli diabetin bütün hallarının 44%-ə qədərini, ürək-damar xəstəliklərinin isə 23%-ə qədərini inkişafını müəyyənləyir (ÜST,

2013). Piylənmənin ümumi iqtisadi zərəri xərçəng xəstəliyi ilə müqayisədə daha çoxdur. Eyni zamanda, artıq çəki bir çox xəstəliklərin inkişafı üçün düzəldilə bilən risk faktorlarından biri kimi tanınır, həmçinin xəstələnmə və ölümün aradan qaldırılma bilən səbəbidir [1]. Heç kimə sirr deyil ki, artıq çəki (piylənmə) probleminin "kökləri" erkən uşaqlıq dövründə, yəni həyat tərzini və qidalanma nümunələrinin, dad üstünlüklərinin və fiziki fəaliyyət səviyyəsinin fərdin bütün sonrakı həyatı üçün proqramlaşdırıldığı vaxtda olur. Uşaqlarda piylənmə onların fiziki və emosional rifahına təsir göstərir, həmçinin daha yetkin yaşda sağlamlıq riski daşıyır. Uşaqlarda artıq çəki və ya piylənmə çox vaxt yetkinlik yaşına qədər davam edir və ürək-damar xəstəliklərinə, 2-ci tip şəkərli diabetə səbəb olur [2]. Artıq bədən çəkisi olan uşaqlarda yetkinlik dövründə piylənmə ehtimalı normal bədən çəkisi olan uşaqlara nisbətən 5 dəfə yüksəkdir [2]. Belə ki, oturaq həyat tərzini, qeyri-sağlam qidalanma və yuxu pozğunluğu uşaqlarda artıq çəki və piylənməyə səbəb ola bilər. Uşaq və yeniyetmələrdə piylənmənin qarşısının alınmasının əsasını həyat tərzinin dəyişdirilməsinə, sağlam qidalanma vərdislərinin və fiziki fəaliyyətin inkişafına yönəlmiş müdaxilələr təşkil edir [3]. Uşaq və yeniyetmələrdə artıq çəki və piylənmənin qarşısının alınması təkcə uşaqlıq dövründə deyil, həm də yetkinlik dövründə də sağlamlığa faydalı təsir göstərə bilər. Buna görə də, artıq çəki və ya piylənmənin inkişaf mexanizmlərinin öyrənilməsi, eləcə də, xəstəlik üçün tədqiq olunan risk faktorlarının hər birinin proqnostik əhəmiyyətinin aydınlaşdırılması bizi uşaqlarda piylənmənin qarşısının alınması üçün effektiv proqramın yaradılmasına daha da yaxınlaşdırma bilər.

Mövzunun aktuallığı. Günümüzdə inkişaf etmiş və inkişaf etməkdə olan ölkələrin mühüm sağlamlıq problemlərindən biri piylənmədir. Piylənmə dünyada ən çox yayılmış xroniki xəstəliklərdən biridir [4]. Gün ərzində qəbul edilən enerjinin sərf olunan enerjiden çox olması müsbət enerji balansının yaranmasına səbəb olur ki, bu da piylənmənin yaranmasına gətirib çıxardır. Artıq çəki (piylənmə) orqanizmdə piy toxumasının artması hesabına yaranır və buna səbəb piy toxumasında insan sağlamlığına zərər yetirəcək dərəcədə anormal və ya hədsiz dərəcədə piyin toplanmasıdır. Problemin global miqyası piylənmənin epidemik dərəcəsi ilə müəyyən edilir [5].

Son zamanlarda artıq çəkiddən (piylənmədən) əziyyət çəkən uşaq və yeniyetmələrin sayı artmaqdadır. Mütəxəssislərin fikrincə, kök uşaqların böyüyüb yetkinlik yaşlarında kök qalması onların sağlamlığı üçün ciddi risk yaradır. Lancet təhlilinin açıqlanması dünyada qeyd olunan Dünya Piylənmə Gününə təsadüf etmişdir [5]. Dünya Piylənmə Federasiyasının qeyd etdiyinə görə, piylənmə səbəbindən əmələ gələn xəstəliklərin müalicəsinə 2025-ci ildən başlayaraq hər il dünya üzrə təxminən 1213 milyard dollar xərclənəcək. Ən yüksək sürətlə uşaqların piylənməsi Şərqi Asiya ölkələrində müşahidə edilir [6].

Tədqiqatçıların qeyd etdiyinə görə, indiki tendensiya qüvvədə qalsa, yaxın gələcəkdə dünyada köklərin sayı, çəkisi normadan az olanların sayını üstələyəcək. 2000-ci ildə pik səviyyəyə çatdıqdan sonra

çəkisi normadan az olan qız və oğlanların sayı dünyada ildən-ilə azalmağa doğru dəyişir. 2020-ci ildə 192 milyon uşaq və yeniyetmənin çəkisi normadan az olmuşdur [6]. Bu, həmin yaşda olan kök uşaqların sayından xeyli çox olsa da, bu sahədə tendensiyanın dəyişdiyi qeyd olunur.

Şərqi Asiya, Latın Amerikası və Karib hövzəsi ölkələrində cəmi bir neçə onillik ərzində uşaqlarda çəki çatışmazlığı problemi piylənmə problemi ilə əvəzlənib. Ümumilikdə isə dünyada 213 milyon uşaq və yeniyetmənin, hələlik piylənmə həddinə çatmasa da, kök olduğu qeyd olunur [7].

Yüksək gəlirli ölkələrdə uşaq və yeniyetmələr arasında piylənmə halları çox yüksəkdir. Bu qrupa daxil olan Birləşmiş Ştatlar kök uşaqların sayına görə ən yuxarı yerdədir. Tədqiqatçılar bu global epidemiyanın səbəbinin ərzaq marketinqi və uğursuz siyasət nəticəsi olduğunu deyirlər.

Ümumilikdə 1975-ci ildən 2020-ci ilə qədər piylənmənin rastgəlmə tezliyi 3 dəfəyə qədər artıb. 2020-ci ildə dünya əhalisinin 119 milyardı artıq çəkiddən, bunun 650 milyonu isə piylənmədən əziyyət çəkir [8].

Yeni tədqiqatların nəticələrinə görə son 40 il ərzində piylənmə əmsalı 10 dəfə artıb, bu isə 124 milyon oğlan və qızın hazırda aşırı kök olduğu deməkdir. Hesablamalara görə, Azərbaycanda qızlar arasında piylənmə 4,4%, oğlanlar arasında isə 5,3% təşkil edir. Belə ki, piylənmənin səbəbləri birincili və ikincili olmaqla iki yerə ayrılır. Piylənmənin geniş yayılmasının səbəbi həyat tərzimizdir. Rahat və oturaq həyat tərzini burada ciddi rol oynayır. Buna görə inkişaf etmiş ölkələrdə insanlar piylənmədən daha çox əziyyət çəkir [9]. Piylənmənin birinci səbəbi özümüzdən asılı hallarla əlaqədardır. Bu, qidalanma və həyat tərzimizlə bağlıdır. Fast-food qidalardan, qazlı içkilərdən istifadə, fiziki aktivliyin aşağı olması piylənmə tezliyini artıran amillərdəndir [10]. Piylənmənin ikinci səbəbinə isə genetik, endokrin xəstəliklər, bəzi dərman preparatlarının istifadəsi aiddir.

Tədqiqatın məqsədi. Hazırkı tədqiqatın məqsədi uşaq və yeniyetmələrdə artıq çəkini inkişafına təsir edən risk faktorlarının aşkarlanması və piylənmənin profilaktikası və müalicəsində effektiv üsulların qiymətləndirilməsidir.

Tədqiqatın materialı və müayinə metodları. Tədqiqata cəlb olunanlar klinikalara artıq çəki şikayəti ilə əlaqədar müraciət edən 4-9 yaşlı uşaqlar və 13-17 yaşlı yeniyetmələrdir. Tədqiqatda iştirak edən könüllülər üçün tədqiqatın məqsədi və ehtimal olunan risklər haqqında məlumat verilir.

Ümumi müayinə zamanı 2015-ci ildə 586 uşaqda ilk dəfə piylənmə aşkar edilmişdir. Əhalinin hər 100000 nəfərinə bu göstərici 23 nəfər təşkil etmişdir. 2016-cı ilin əvvəlinə əhalinin hər 100000 nəfərinə düşən bu xəstələrin sayı isə 51 nəfər olmuşdur. Ötən il piylənmə aşkar edilmiş uşaqların 46,8%-i qız, 53,2%-i oğlan olmuşdur. Piylənmə aşkarlanmış qızların 66,8%-i 13 yaşına qədər, 33,2%-i 14-17 yaşlarında olmuşdur. Oğlanlarda isə bu göstərici müvafiq olaraq 65,1% və 34,9% təşkil etmişdir.

Tədqiqatın müzakirəsi.

1. Uşaqlarda artıq çəkinin yaranma səbəbləri:

Uşaqlarda piylənmənin inkişafında həm genetik, həm də mühit faktorlarının, həyat tərzinin rolu böyükdür. İrsi meyil haqqında danışarkən, bədəndəki metabolik proseslərin xüsusiyyətlərinin genetik olaraq ötürülməsi nəzərdə tutulur. Çox vaxt köklük deyil, çox yemək verdiyi və ümumiyyətlə, həyat təzi ötürülür. Genetik meyil xarici amillərin təsiri altında reallaşır.

Doğuş zamanı bədən kütləsi normadan artıq olan uşaqlar (4 kq-dan artıq) risk qrupuna aiddirlər. Bundan əlavə, piylənmə ciddi patoloji vəziyyətlər və genetik xəstəliklər nəticəsində də inkişaf edə bilər.

Uşaqlarda piylənmənin 90%-i alimentar piylənmədir, yəni həddindən artıq və ya çox kalorili qida qəbulu və aşağı fiziki aktivliyin nəticəsidir [11]. Bu səbəbdən uşaq doğulandan onun qidalanmasına düzgün şəkildə yanaşmaq lazımdır. Körpələrdə piylənmə yüksək kalorili süni süd qarışıqlarının həddindən artıq yedizdirilməsi nəticəsində əmələ gələ bilər. Əz azı ilk altı ay ərzində ana südü ilə qidalanma erkən piylənmənin qarşısını ala bilər.

Uşaqlarda fiziki aktivlik də kifayət qədər deyildir. Belə ki, uşaqlar günün çox hissəsini məktəbdə və ev tapşırıqlarını yerinə yetirərkən masa arxasında oturmaqla, kompüter oyunları oynamaqla, televizora, telefona və ya planşetə baxmaqla keçirirlər, yəni kifayət qədər sıx zehni yükə sahib olduqları halda, çox az hərəkət edirlər. Bu da uşaqlarda artıq çəkiyə səbəb olur. Uşaq məktəbdə, ailədə xroniki stres vəziyyətində və ya sosial təcridə ola bilər. Bu zaman uşaq müsbət emosiyalar qazanmaq, özünü stressdən qorumaq üçün yollar axtarır. Yemək uşaq üçün sevinc və zövq mənbəyinə çevrilə bilər ki, bu da piylənməyə səbəb olan amilə çevrilir.

Buna görə də, uşaqlarda artıq çəki və ya piylənmənin qarşısının alınmasında onların fərdi xüsusiyyətlərini nəzərə alaraq, sağlam həyat tərzinin mühüm tərkib hissəsi kimi qidalanma prinsiplərinə, yaşa uyğun fiziki fəaliyyətin normalarına riayət edilməsi və artıq bədən çəkisinə daimi nəzarətin olması məqsəduyğun sayılır.

2. Piylənmədə risk faktorları: Uşaqlarda artıq çəki və piylənmənin əsas səbəbi istehlak edilən və sərf olunan kalorilər arasında enerji balansının pozulmasıdır. Uşaq və yeniyetmələrdə piylənmə əsasən qeyri-sağlam qidalanma və aşağı fiziki fəaliyyətlə əlaqələndirilir. Uşaqlarda artıq çəki əldə etmə riskini aşağıdakılar artırır:

- **Qidalanma.** Fast food, bişmiş məhsullar və avtomat qəlyanaltılar kimi yüksək kalorili qidaları müntəzəm olaraq yemək uşağınızın kökəlməsinə səbəb ola bilər [10]. Şirniyyat və desertlər də çəki artımına səbəb ola bilər və getdikcə daha çox sübut şəkərli içkilərin, o cümlədən meyvə şirələrinin və idman içkilərinin bəzi insanlarda piylənmənin günahkarı olduğunu göstərir.

- **Hərəkətsizlik.** Çox hərəkət etməyən uşaqlar çox kalori sərf etmədikləri üçün kökəlmə ehtimalı onlarda daha yüksəkdir [11]. Televiziya izləmək və ya video oyunları oynamaq kimi oturmaq fəaliyyətlərə çox vaxt sərf etmək də problemə kömək edir.

- **İrsiyyət.** Əgər uşağın ailəsində artıq çəkiddən əziyyət çəkənlər varsa, onun kökəlmə ehtimalı daha yüksək ola bilər [12]. Bu, xüsusilə yüksək kalorili qidaların həmişə mövcud olduğu və fiziki fəaliyyətin təşviq edilmədiyi bir mühitdə doğrudur.

- **Psixoloji amillər.** Şəxsi və ailə stressi uşağın piylənmə riskini artırma bilər. Bəzi uşaqlar problemlərin öhdəsindən və ya emosiyaların öhdəsindən gəlmək, məsələn, stress və ya cansıxıcılıqla mübarizə aparmaq üçün həddindən artıq yeyirlər.

- **Sosial-iqtisadi amillər.** Bəzi icmalarda insanların məhdud resursları və supermarketlərə çıxışı məhduddur. Nəticədə, onlar dondurulmuş yeməklər, krakerlər və peçenye kimi tez xarab olmayan rahat qidalar əla bilirlər.

- **Müəyyən dərmanlar.** Bəzi dərmanlar piylənmə riskini artırma bilər. Bunlara prednizon, litium, amitriptilin, paroksetin (Paxil), gabapentin (Neurontin, Gralise, Horizant) və propranolol (Inderal, Hemangeol) daxildir.

3. Piylənmənin yaratdığı fəsadlar: Ümumdünya Səhiyyə Təşkilatına görə, sağlamlıq "sadəcə xəstəliyin və ya zəifliyin olmaması deyil, eyni zamanda yaxşı fiziki, əqli və sosial rifahdır". Bu səbəbdən faydalı qidaları rasionumuza daxil etmək, aktiv həyat tərzini seçmək, stressin təhlükəsini dərk etməyi və onunla mübarizə aparmağı öyrənmək sağlam həyat üçün atılacaq addımdır. İnsanın sağlamlığı ilk növbədə özündən asılıdır. Sağlam həyat təzi, özünə və başqalarına qarşı məsuliyyətli münasibət, sağlamlığın və uzunömürlülüyn qorunması, eləcə də xəstəliklərin qarşısının alınması üçün zəruri şərtlərdir. Uşaqlarda və yeniyetmələrdə piylənmə onların fiziki, sosial və emosional rifahında ağırlaşmalara səbəb olur.

Uşaqlarda piylənmə ciddi sağlamlıq problemlərinə səbəb ola bilər; mədə-bağırsaq sistemi xəstəlikləri (qəbizlik, ishal, xolesistit, pankreatit və s.), ürək-damar sistemi xəstəlikləri (arterial hipertoniya, ürəyin işinin çətinləşməsi), ateroskleroz, endokrin və metabolik patologiyalar (insulinə müqavimət, 2-ci tip şəkərli diabet, cinsi inkişaf pozuntuları), sümük-əzələ sistemi və oynaq patologiyaları (artroz, skolioz, yastıpəncəlik) və s. Bundan başqa, uşaqlarda müxtəlif psixoloji çətinliklər, özgüvən əskikliyi, komplekslər meydana çıxma bilər [13].

a) Fiziki ağırlaşmalar: Piylənmə və ya artıq çəki ağır yanaşı patologiyalarla müşahidə olunur. Uşaqlarda piylənmənin fiziki ağırlaşmaları aşağıdakıları əhatə edir:

- **2-ci tip şəkərli diabet.** Bu xroniki vəziyyət uşağınızın bədəninin şəkərdən (qlükoza) istifadəsinə təsir göstərir. Piylənmə və oturmaq həyat təzi 2-ci tip diabet riskini artırır [14].

- **Yüksək xolesterol və yüksək qan təzyiqi.** Səhv bir pəhriz uşağınızda bu şərtlərdən birini və ya hər ikisini inkişaf etdirə bilər. Bu amillər damarlarda ləvhələrin yığılmasına kömək edə bilər ki, bu da damarların daralmasına və sərtləşməsinə, bəlkə də daha sonra infarkt və ya vuruşa səbəb ola bilər.

- **Birgə ağrı.** Əlavə çəki omca və dizlərdə əlavə stress yaradır. Uşaqlardakı piylənmə omca, diz və kürək nahiyyəsində ağrılara səbəb ola bilər [15].

• **Nəfəs alma problemləri.** Astma daha çox çəkisi olan uşaqlarda rast gəlinir. Bu uşaqlarda obstruktiv yuxu apnesini inkişaf etdirmək ehtimalı daha yüksəkdir, bu, uşağın nəfəsinin dəfələrlə dayandığı və yuxu zamanı başladığı bir potensial, ciddi pozğunluqdur.

• **Alkoqolsuz yağlı qaraciyər xəstəliyi (NAFLD).** Adətən heç bir əlamət göstərməyən bu pozğunluq qaraciyərdə yağ yığılmasına səbəb olur. NAFLD çapıq və qaraciyərin zədələnməsinə səbəb ola bilər.

b) Sosial və emosional ağurlaşmalar: Piylənmədən əziyyət çəkən uşaqlar həmyaşıdları tərəfindən zorakılığa məruz qala bilərlər. Bu, özünə hörmətin itirilməsi və depressiya ilə nəticələnə bilər [13].

4. Piylənmənin qarşısının alınması üçün atılan addımlar: Uşaqlarda artıq çəki artımının qarşısını almaq üçün aşağıdakıları edə bilərik:

• **Yaxşı nümunə göstərmək.** Sağlam qidalanma və müntəzəm fiziki fəaliyyəti bir ailə işi etmək məsləhətdir. Hər kəs bundan faydalanacaq və heç kim özünü xüsusi hiss etməyəcək.

• **Sağlam qalınaltıların hazırlanması.** Seçimlər arasında yağsız havada qızardılmış popkorn, az yağlı qatıqlı meyvələr, humuslu körpə yerkökü və ya az yağlı südlü tam taxıl taxılları daxildir [12].

• **Bir neçə dəfə yeni yeməklərin təklif edilməsi.** Əgər uşaq yeni yeməyi dərhal bəyənərsə, ruhdan düşmək lazım deyildir. Qəbul etmək üçün adətən bir qidaya bir neçə dəfə məruz qalma tələb olunur.

• **Uşağın kifayət qədər yuxu aldığından əmin olmaq.** Bəzi tədqiqatlar göstərir ki, çox az yuxu piylənmə riskini artırır. Yuxusuzluq iştahın artmasına səbəb olan hormonal balanssızlığa səbəb ola bilər [16]. Həmçinin, uşağı ildə ən azı bir dəfə pediaatra müayinə etdirmək vacibdir. Dərman vasitələrinin həkimə müraciət etmədən nəzarətsiz istifadəsi əksər hallarda uşaqlarda mənfi reaksiyalara səbəb olur. Belə ki, mütəxəssislər ciddi xəstəliklərin inkişafını, o cümlədən allergik reaksiyaları, qaraciyərin toksiki zədələnməsini, zehni fəaliyyətin pisləşməsinə, görmə qabiliyyətinin azalması və ya tamamilə itirilməsini, ürək və damar xəstəliklərini və s. qeyd edirlər. Ev şəraitində həkim nəzarəti olmadan aparılan müalicə xəstəliyin klinik gedişatını həm gizlədə, həm də dəyişdirə bilər. Nəticədə xəstəliyin diaqnozu və müalicəsi ilə bağlı müəyyən çətinliklər yaranır. Evdə həkim nəzarəti olmadan dərmanların istifadəsi yolverilməzdir.

5. Uşaqlarda piylənmənin müalicənin effektiv üsulları: Piylənmənin müalicəsi zamanı əsas tədbirlər bədən kütləsinin aşağı salınmasına, yanaşı gedən xəstəliklərin müalicə olunmasına, alınan nəticələrin saxlanmasına yönəldilməlidir. Bədən kütləsini azaltmaq üçün uşağın həyat tərzini dəyişdirmək lazımdır, yeni yaşa uyğun qidalanma rasionu və fiziki aktivlik (gimnastika, üzgüçülük və s.) təmin olunmalıdır. Həkimlə birlikdə uşağın gündəlik kalori miqdarı hesablanmalı və valideynlər buna əməl etməlidir. Əvvəlcə, uşağın pəhrizində tərkibində heyvani yağlar və asan həzm olunan karbohidratlar olan qidaları məhdudlaşdırmaq tövsiyə olunur [12]. Şiirlərdə çox miqdarda

şəkər olduğu üçün pəhrizdə tərəvəzlərə üstünlük verilməlidir [10]. Tərkibində piy və duzun miqdarı çox olduğundan, kolbasa verilməməlidir. Uşaq şirniyyat istəyərsə, əvəzinə quru meyvə vermək daha yaxşıdır. Körpələrə əlavə qida kimi sıyıqlar deyil, tərəvəz püreləri verilməlidir. Piylənmə zamanı pediaatr və uşaq endokrinoloqu ilə yanaşı genetik, uşaq kardioloqu, uşaq gastroenteroloqu, uşaq ortopedi, neyrocərrah və uşaq psixoloqunun dəstəyi də tələb oluna bilər. Piylənmədən əziyyət çəkən uşaqlara masaj, iqlorefleksoterapiya, hidroterapiya, psixoterapiya əsas göstərişdir.

Nəticə. Uşaq və yeniyetmələrdə artıq çəki və ya piylənmə XXI əsrin ən böyük sağlamlıq problemlərindən biridir. Piylənmə - ekoloji, biopsixososial, genetik və epigenetik amilləri özündə birləşdirən mürəkkəb bir xəstəlikdir. Piylənmə uşaq və yeniyetmələrdə əhəmiyyətli tibbi, psixososial və neyrokoqnitiv pozğunluqlara səbəb olur. Uşaqlarda piylənmənin yetkinlik yaşına qədər davam etməsi, uzunmüddətli sağlamlıq və həyat keyfiyyətinə təsirinin qarşısını almaq üçün onun səbəblərini başa düşməyi son dərəcə vacib edir. Uşaq və yeniyetmələrdə piylənmənin qarşısının alınması və müalicəsi üçün tərtib edilən proqramların əksəriyyəti ailə və ya məktəb səviyyəsində müdaxilələrə əsaslanır. Bununla belə, hazırda istifadə olunan müdaxilələrin heç biri piylənmənin epidemik böyüməsini təkbəşinə dayandıra bilməz. Qeyd etmək lazımdır ki, uşaq və yeniyetmələrdə piylənmə problemi ətraf mühit amillərinin və davranış reaksiyalarının formalaşdığı kritik inkişaf dövrlərinin nəzərə alınmasını tələb edir. Belə situasiyada piylənmənin müalicəsinin və profilaktikasının effektiv strategiyasının lazımlığı aydındır. Uşaqlarda piylənmənin diaqnostikasının, müalicə vasitələrinin və seçim metodlarının təqdim olunan tövsiyələri piylənmənin tədqiqatında və müalicəsində lider olan müxtəlif ölkələrin təcrübəsinə əsaslanmışdır. Beləliklə, sağlam qidaları və əyləncəli fəaliyyətləri gündəlik həyatlarının tərkib hissəsinə çevirmək uşaqlarımızın inkişafına kömək edəcək, sağlamlılıqlarını yaxşılaşdıracaq və onları ömür boyu müsbət, sağlam seçimlər etməyə hazırlayacaqdır.

Ədəbiyyat.

1. Roberto CA, Swinburn B, Hawkes C, et al. Patchy progress on obesity prevention: emerging examples, entrenched barriers, and new thinking. *Lancet*. 2015; 385(9985):2400–2409. Doi: 10.1016/S0140-6736(14)61744-X.
2. Who.int [internet]. World Health Organization Fact sheet № 311. Obesity and overweight [updated 2016 Jan; cited 2016 Jun 13]. Available from: <http://www.who.int/mediacentre/factsheets/fs311/en>.
3. Mckinsey.com [internet]. Dobbs R, Sawers C, Thompson F, et al. How the world could better fight obesity [updated 2014 Nov; cited 2016 Jun 13]. Available from: <http://www.fooddrinktax.eu/mckinsey-institute-world-better-fight-obesity/>.
4. Sudmed.smolensk.ru [интернет]. Избыточный вес и ожирение, как причина повышения смертности [доступ от 03.05.2016]. Доступ по ссылке: sudmed.smolensk.ru/izbitocniy-ves.htm.

5. Lobstein T, Jackson-Leach R, Moodie ML, et al. Child and adolescent obesity: part of a bigger picture. *Lancet*. 2015;385(9986): 2510–2520. doi: 10.1016/S0140-6736(14)61746-3.
6. Аверьянов А.П. Ожирение у детей и подростков : клинико-метаболические особенности, лечение, прогноз и профилактика осложнений: автореф. дис. д-ра мед. наук / А.П. Аверьянов. – Саратов, 2009. – 26 стр.
7. Баранов А.А. Патогенетические основы формирования атопической патологии у детей / А. А. Баранов, А.А. Джумагазиев, Д.А. Безрукова // Астраханский медицинский журнал. – 2010. – Т. 5, № 1. – Стр. 7–11.
8. Билим М.В. Клиническое значение эндокринно-иммунных нарушений в генезе олигоменореи у девочек-подростков с ожирением: автореф. дис. канд. мед. наук / М.В. Билим. – Ростов-н/Д., 2015. – 26 стр.
9. Богданьянц М.В. Биоимпедансометрия – инструмент раннего выявления детей с избыточной массой тела и ожирением / М.В. Богданьянц, Д.А. Безрукова, Н.Р. Брысина, Л.М. Акмаева, О.В. Усаева, А.Ю. Сысоева, Д.К. Булатова // Актуальные вопросы современной медицины: материалы Международной конференции Прикаспийских государств (Астрахань, 6–7 октября 2016 г.). – Астрахань: Издательство АГМУ, 2016. – Стр. 53–56.
10. Богданьянц М.В. Возможные факторы риска развития ожирения у детей и подростков / М.В. Богданьянц, А.А. Джумагазиев, Д.А. Безрукова / Наука и образование сегодня. – 2016. – № 6 (7). – Стр. 93–94.
11. Васюкова О.В. Рекомендации по диагностике, лечению и профилактике ожирения у детей и подростков / О.В. Васюкова, И.Я. Конь, З.Г. Ларионова, И.В. Леонтьева, Е.В. Павловская, Г.И. Порядина, В.Б. Розанов, А.В. Стародубова, М.Ю. Щербакова; под науч. ред. А. А. Александрова, В.А. Пятеркова. – М.: Практика, 2015. – 136 стр.
12. Вербовой А.Ф. Грелин и лептин у юношей с пубертатным ожирением до и после проведения орального глюкозотолерантного теста // А.Ф. Вербовой, О.Н. Решетова, И.А. Фомина, И.А. Цанава // Фарматека. – 2015. – № 17. – Стр. 60–63.
13. Гусева А.А. Клинико-метаболические особенности состояния гепатобилиарной системы у детей с избыточным весом и ожирением: автореф. дис. канд. мед. наук / А.А. Гусева. – М., 2015. – 26 стр.
14. Джумагазиев А.А. Динамика распространенности избыточной массы тела и ожирения у детей города Астрахани / А.А. Джумагазиев, Н.Р. Брысина, Н.С. Лихачева, Д.А. Безрукова, М.В. Богданьянц, Л.М. Акмаева, О.В. Усаева // Актуальные вопросы современной медицины: материалы Международной конференции Прикаспийских государств (Астрахань, 6–7 октября 2016 г.). – Астрахань: Издательство АГМУ, 2016. – Стр. 84–85.
15. Джумагазиев А.А. Пищевые предпочтения у детей с избыточной массой тела и ожирением / А.А. Джумагазиев, Д.А. Безрукова, М.В. Богданьянц, Ф.В. Орлов, Л.М. Акмаева, О.В. Усаева // Вопросы питания. – 2016. – Т. 85, № S2. – Стр. 47–48.
16. Джумагазиев А.А. Проблема ожирения у детей в современном мире: реалии и возможные пути решения / А.А. Джумагазиев, Д.А. Безрукова, М.В. Богданьянц, Ф.В. Орлов, Д.В. Райский, Л.М. Акмаева, О.В. Усаева, Л.С. Джамаев // Вопросы современной педиатрии. – 2016. – Т. 15, № 3. – Стр. 250–256.
17. Джумагазиев А.А. Прогностическое значение некоторых факторов риска развития ожирения у детей / А.А. Джумагазиев, Г.И. Сучков, Н.В. Лихачева, М.А. Ланцева // Аллергология и иммунология. – 2013. – № 2. – Стр. 104.
18. Джумагазиев А.А. Распространенность избыточной массы тела и ожирения у астраханских детей / А.А. Джумагазиев, О.И. Паньковская, Н.В. Лихачева // Здоровое питание с рождения: Медицина, образование, пищевые технологии: материалы IX Российского форума (7-8 ноября 2014 года, Санкт-Петербург). – СПб.: 2014. – Стр. 43–44.
19. Каладзе Н.Н. Роль грелина в формировании метаболических нарушений у детей с артериальной гипертензией / Н.Н. Каладзе, О.К. Алешина, Н.А. Ревенко // Российский вестник перинатологии и педиатрии. – 2015. – № 1. – Стр. 54–57.
20. Конь И.Я. Гормоны-регуляторы энергетического гомеостаза в женском молоке: скорость роста младенцев первых месяцев жизни / И.Я. Конь, Н.М. Шилина, М.В. Гмошинская, Т.А. Иванушкина // Вопросы питания. – 2011. – Т. 80, № 4. – Стр. 73–78.
21. Косыгина А.В. Гормоны жировой ткани – адипонектин и висфатин и экспрессия контролируемых их генов при ожирении у детей : автореф. дис. канд. мед. наук / А.В. Косыгина. – М., 2011. – 25 стр.

PEDAGOGICAL SCIENCES

STUDY ON THE INFLUENCE OF PHYSICAL EDUCATION CURRICULUM ON ADOLESCENT MENTAL HEALTH FROM THE PERSPECTIVE OF "BODY AND MEDICINE INTEGRATION"

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Abstract

In contemporary society, adolescent mental health issues such as depression and anxiety are on the rise, posing a significant global public health challenge. Traditional interventions predominantly focus on medical treatment or psychological counseling while overlooking the positive role of physical exercise. Integrative Medicine and Sports (IM&S), an innovative paradigm, emphasizes combining physical education with medical knowledge to promote adolescent mental health through structured exercise programs and psychological education. This study adopts an IM&S perspective to investigate the impact of physical education on adolescent mental health, develop optimal intervention models, and validate their effectiveness through empirical research, thereby providing scientific evidence for adolescent health promotion.

Keywords: sports and medicine integration; youth sports; health promotion; mental health

INTRODUCTION

In recent years, adolescent mental health has emerged as a major global public health challenge with growing diversity. On one hand, physical health issues such as rising obesity rates and the increasing prevalence of chronic diseases among younger populations have drawn widespread attention in China. On the other hand, mental health disorders including depression and anxiety have seen significant increases, posing a global crisis. As the future of the nation and the hope of the people, adolescents' physical and mental well-being directly impacts the country's long-term development and the nation's prosperity. Therefore, comprehensively improving adolescent health standards is not only a core component of the Healthy China strategy in the new era but also an urgent requirement to achieve the "Healthy China 2030" goals.

According to the WHO's "2023 Report on Adolescent Health", over 360 million adolescents aged 10-19 worldwide face threats from obesity or chronic metabolic diseases, while depression detection rates have risen by 37% compared to a decade ago. In China, the prevalence of anxiety disorders among adolescents has reached 7.8% (as reported in the "National Mental Health Development Report"). This "dual-track crisis" stems not only from social changes like academic pressure and digital media addiction but also exposes the fragmentation of existing health intervention systems—. The medical system prioritizes pathological treatment, while the education system focuses on physical fitness standards, lacking coordination in resource allocation, theoretical frameworks, and implementation approaches[1]. As strategic resources for national development, adolescents' physical and mental health directly impacts human capital quality and sustainable social development capabilities. Therefore, building an integrated health promotion system has become a core task in implementing the "Healthy China 2030" plan, with its urgency further reinforced by the deployment of "strengthening youth sports programs" in the report

of the 20th National Congress of the Communist Party of China.

As an innovative paradigm in health governance, Integrative Medicine and Sports emphasizes the integration of physical education with medical knowledge to jointly promote physical and mental well-being through structured exercise (such as aerobic training and psychological skill education). This concept not only aligns with the health strategy of "shifting disease prevention from 'treating existing illnesses' to 'preventing potential ones'," but also embodies a new approach to comprehensive life-cycle health management. Currently, this integration has achieved significant results in mass sports programs, forming a relatively mature theoretical system and diverse practical models, becoming a crucial initiative under China's Healthy Nation Strategy. However, traditional interventions for adolescents often focus on medical treatment or psychological counseling while neglecting the positive role of physical exercise, resulting in notable shortcomings in mental health promotion measures. From the perspective of Integrative Medicine and Sports, this study aims to explore the impact of physical education on adolescent mental health, develop optimal intervention models, and validate their effectiveness through empirical research. By analyzing existing issues in adolescent sports health promotion (such as lack of mental health interventions and insufficient resource integration), this research proposes targeted solutions to provide scientific evidence and feasible references for improving adolescent physical and mental health levels. This will promote interdisciplinary integration between medicine and sports, enrich the theory of Integrative Medicine and Sports, and support the comprehensive implementation of China's Healthy Nation Strategy.

research on the influence of "body-medical integration" on adolescent mental health

As an innovative paradigm for health promotion, the integration of physical, medical, and mental health

is rooted in profound understanding of life's holistic nature. This concept transcends traditional disciplinary barriers between medicine and physical education, advocating for coordinated development of physical and mental well-being through the organic combination of exercise interventions and health management. Philosophically, it resonates with the wisdom of "harmonizing form and spirit" from traditional Chinese health preservation culture, as emphasized in the <Huangdi Neijing> (Yellow Emperor's Inner Canon): "When the spirit remains inwardly guarded, where does disease come from?" It also aligns with the Western philosophy of mind-body unity. This interdisciplinary integration is not merely a technical addition but a fundamental restructuring based on the complexity of life systems—Human health status always exists in dynamic equilibrium among physiological functions, psychological activities, and social environments. Any intervention focusing on a single dimension cannot achieve lasting benefits[2].

The evolution of modern health sciences has established a robust theoretical foundation for integrating physical and medical approaches. Health ecology theory posits that individual health results from the combined effects of genetic predisposition, behavioral choices, and environmental support. Adolescent mental health issues often manifest as multifaceted interplay: academic stress may trigger anxiety, which in turn causes sleep disturbances and weakens immune function, creating a vicious cycle. Traditional mental health interventions predominantly focus on counseling or medication, yet overlook sports as a crucial regulatory factor. In reality, physical education curricula enhance multiple dimensions of health through structured physical activities: improving cardiovascular function and hormonal balance physiologically; alleviating stress and boosting self-efficacy psychologically; and fostering peer interaction and social belongingness socially. This synergistic effect of multidimensional interventions constitutes the core advantage of integrated physical-health approaches over single-discipline interventions.

The behavior modification theory further elucidates the internal mechanisms through which physical education curricula promote mental health. Social cognitive theory emphasizes that individuals develop self-confidence by mastering specific experiences[3]. When teenagers successfully defend in basketball games or break personal records during swimming training, these tangible physical achievements transform into psychological conviction of "I can do it," significantly enhancing resilience against setbacks. Self-determination theory reveals the crucial role of sports environment design: when physical education curricula meet students' needs for autonomy (such as elective sports), competence (like progressive skill training), and belonging (team collaboration tasks), intrinsic motivation is fully stimulated. For instance, a middle school designed football classes as group cooperative challenge games. As students overcome technical hurdles, they not only improve physical fitness but also build emotional con-

nections through mutual support, resulting in a 32% reduction in depression incidence compared to traditional teaching methods.

The interaction between environment and behavior is systematically explained in ecosystem theory[4]. This framework examines adolescent development across three tiers: micro (family, classroom), meso (school, community), and macro (cultural policies). The innovation of physical education curriculum from the perspective of body-medicine integration optimizes developmental pathways by restructuring micro-system environments. When schools establish emotional regulation corners with relaxation equipment in gymnasiums; when PE teachers collaborate with psychological counselors to design "Exercise-Emotion Diaries"; and when physical performance evaluations incorporate psychological resilience metrics—these environmental modifications immerse students in a culture where "exercise promotes mental health." The effectiveness of such interventions has been validated in practice: At an experimental school combining three weekly PE classes with mindfulness breathing training, students' psychological resilience scores increased by 41% after one semester, significantly surpassing the 19% improvement seen in the control group receiving only counseling.

The theory of life course reveals the strategic value of early intervention through its temporal perspective. Adolescence serves as a critical window for physical and mental development, where healthy behavioral patterns established during this period leave lifelong imprints. Developing regular exercise habits not only provides immediate relief from psychological distress but also reshapes the brain's stress response mechanisms through neural plasticity[5]. Follow-up studies show that adolescents who maintained physical activity during middle school years had a 37% lower incidence of depressive disorders in adulthood. This "exercise reserve" effect acts like building mental health levees—enhancing resilience when facing life's storms. Therefore, sports-curriculum programs guided by the integration of physical education and healthcare fundamentally represent early investments in health capital, with returns spanning the entire life cycle.

It is noteworthy that the integration of physical education and mental health requires overcoming several structural barriers. The tension between schools' long-standing "physical fitness standard-oriented" approach and the "holistic development-oriented" approach to mental health promotion persists. Professional barriers between physical education teachers and psychological counselors hinder deep curriculum integration, while standardized sports facilities lack dedicated psychological intervention zones. Addressing these challenges demands institutional innovation: establishing interdisciplinary teaching research groups, developing integrated curriculum standards, incorporating psychological counselors into physical education teams, and transforming sports spaces into multifunctional wellness centers[6]. A city's "Healthy Campus 2030" initiative adopted this pathway, embedding emotional management modules in PE classes and adding sports function

assessments in school clinics, resulting in a 54% annual decrease in adolescent psychological crisis incidents.

The integration of physical education and healthcare ultimately drives profound transformations in educational philosophy. It transcends the traditional view of sports as mere physical training tools, reestablishing the intrinsic value of physical activity in holistic human development. When students learn emotional regulation through badminton matches and discover willpower strength through marathon perseverance, sports become a crucible for character formation. This "physical-mental cultivation" educational approach aligns with the wisdom of ancient Chinese "Six Arts" education that nurtures mental fortitude through archery and charioteering, while deeply resonating with modern education's emphasis on core competencies. In today's era of escalating adolescent mental health crises, this integration serves not merely as an intervention measure, but as a return to the essence of education—awakening bodily potential to stimulate comprehensive healthy growth throughout life.

The current situation of integrated development of body and medicine

The development goal of sports-medicine integration lies in better meeting the needs of the entire population in China for chronic disease prevention, health promotion, and rehabilitation through scientific exercise. From a supply perspective, this involves integrating sports with medicine to provide clusters of products and services related to mental health, forming the sports-medicine integration industry. Sports-medicine integration reorganizes the divergent elements between healthcare and sports sectors, focusing on three "comprehensiveness": full life cycle coverage, universal health, and comprehensive services[7]. However, current social practices in sports-medicine integration still face pressing issues: unclear conceptual guidance leading to insufficient awareness of proactive health among

multiple stakeholders; weak institutional frameworks causing operational constraints in sports-medicine integration management; imbalanced supply-demand dynamics resulting in suboptimal service quality and efficiency; and inadequate resource guarantees limiting sustainable development potential. Therefore, the following approaches should be adopted to optimize the development of the sports-medicine integration health industry system: First, prioritize people's health by actively reinforcing the concept of proactive health awareness; Second, focus on institutional construction to effectively resolve operational bottlenecks in sports-medicine integration management; Third, center on supply-demand alignment to enhance service quality and efficiency in sports-medicine integration; Fourth, leverage innovation in resources to accelerate addressing shortcomings in integrated sports-medicine development.

The 2023 China National Mental Health Development Report indicates that the depression detection rate among adolescents aged 14-18 reached 24.6%, a 3.2 percentage point increase from 2020, with severe depression accounting for 7.2%. A 2022 Ministry of Education survey found anxiety symptoms in middle school students hit 31.8%, significantly higher in girls (35.1%) than boys (28.5%). CDC data shows adolescent suicide rates jumped 25.7% in 2021 compared to 2019, making psychological crises the second leading cause of death for 15-19-year-olds. When physical health and mental issues intertwine, overweight/obese teens (BMI ≥ 24) face 2.3 times greater depression risk than those with normal weight (95% CI: 1.8-3.0). Among daily screen time exceeding 4 hours, 41.5% experience mood regulation disorders (vs. 16.3% in groups under 1 hour), highlighting the growing digital divide.

area	Innovation initiatives	fraction of coverage
Shenzhen	"Exercise prescribers" enter the campus	100% public middle school
Zhejiang	Psychological resilience evaluation was added to physical education test	40% in 2023
Shanghai	Medical insurance pays for school sports interventions	Three categories of projects are covered by medical insurance

Empirical data on the effect of physical-mental integration intervention — Improvement of psychological indicators by exercise intervention

The practical efficacy of integrated physical and mental health interventions has been rigorously validated through scientific research. A controlled trial targeting adolescents demonstrated that structured exercise programs significantly improved mental health indicators: Participants in the experimental group who engaged in 45-minute aerobic exercise three times weekly showed a 36.4% decrease in depression scale (PHQ-9) scores compared to pre-intervention levels, representing a 4.5-fold reduction rate ($p < 0.001$). This improvement was strongly positively correlated with elevated serum neurotrophic factor concentra-

tions 28.7ng/mL ($r=0.62$), indicating that exercise enhances emotional regulation by promoting neural plasticity.

Aerobic exercise group (3 times a week $\times$ 45min):

The depression scale (PHQ-9) score decreased by 36.4% (compared group decreased by 8.1%, $p < 0.001$)

Increased serum BDNF concentration 28.7ng/mL (positive correlation with mood improvement $r=0.62$)

Team sports group (basketball/football):

Social anxiety decreased by 52% (individual exercise group decreased by 31%)

The average daily decrease of salivary cortisol was 18.3%

These findings have been further validated through large-scale educational practices. The Beijing Sunshine Mental Sports Class Project (2022-2023) incorporated sports interventions into regular curricula,

resulting in a 54% sharp decline in psychological crisis incidents among participating students and an 11.2-point improvement in academic performance (effect size $d=0.49$), effectively refuting the misconception that "sports compete with studies." Meanwhile, innovative practices at Guangdong's Sports-Medicine Integration Demonstration School revealed the potential of precision intervention: By establishing a dynamic feedback system through dual-mode monitoring of "exercise load + heart rate variability," the proportion of anxious students dropped from 29.7% to 16.4% within just six months[8]. These cases collectively demonstrate that when physical education courses transcend traditional skill training frameworks by integrating medical assessment and psychological intervention techniques, they can become highly effective vehicles for promoting adolescent mental health.

The dilemma of promoting high-quality development

Multiple stakeholders including families, schools, communities, and healthcare institutions have failed to establish an effective collaborative mechanism in promoting youth sports and health initiatives, resulting in fragmented resources, information gaps, and inconsistent actions. Firstly, as the primary learning environment for adolescents, families play a crucial role in shaping children's sports awareness and setting behavioral examples. However, many households lack adequate sports education knowledge and fail to provide sufficient guidance or support for their children's physical development. Additionally, parents often prioritize academic performance and talent cultivation over physical health, leaving adolescents without adequate motivation or support for participating in sports activities and receiving health education. Secondly, while schools serve as the core of the educational system and offer physical education courses, there remains room for improvement in diversifying sports programs, enhancing engagement, and fostering sportsmanship[9]. Thirdly, societal understanding of sports-health integration remains inadequate. Although this integration has become a new trend in health promotion, public awareness in this field continues to be limited. Many individuals lack comprehension of the concept, significance, and practical applications of sports-health integration, leading to difficulties in forming effective support and coordination in implementation.

The integration of sports and medicine in adolescent mental health promotion is facing severe structural challenges. The primary bottleneck stems from coordination barriers among stakeholders: physical education teachers in schools, psychologists in healthcare systems, and instructors from community sports organizations should form a tripartite collaborative network, yet they operate in silos due to administrative barriers[10]. A typical case from a key high school illustrates this issue: When the physical education department designed stress-reduction exercise programs, the school clinic failed to provide physiological data for anxious students due to communication gaps. Similarly, psychological counseling centers developed exercise therapy plans that couldn't be implemented because of

teachers' limited professional understanding. This fragmented "each department handles its own" approach led to 38% of intervention plans in Beijing's "Exercise Prescription" program being suspended due to poor interdepartmental coordination. More alarmingly, during adolescent psychological crisis management, physical education teachers often become the last to notice student abnormalities, missing the critical window for exercise interventions.

The talent gap directly threatens the sustainability of sports-medicine integration. The disciplinary divide in current training systems means physical education majors rarely study clinical psychology courses, while medical students lack exercise physiology training. This results in a severe shortage of interdisciplinary professionals capable of prescribing exercise regimens and providing psychological counseling. Research shows only 7.3% of physical education teachers nationwide possess basic psychological assessment skills, with less than 4% of school nurses holding qualifications for exercise intervention. A Guangdong demonstration school attempting "exercise-cognitive" dual-track interventions failed when teachers couldn't interpret students' heart rate variability data during workouts, rendering biofeedback training superficial. Such professional deficiencies are particularly pronounced at the grassroots level—A psychology teacher from a western county middle school admitted that when dealing with students showing depressive tendencies, they could only suggest "run more" without offering scientific exercise plans, highlighting a critical mismatch between talent cultivation and job requirements.

The imbalance in resource allocation has exposed deep-seated contradictions in institutional design. While key coastal cities' high schools are equipped with million-dollar psychological monitoring laboratories, rural schools in central and western China struggle to even update basic physical fitness testing equipment[11]. This resource gap directly leads to polarized intervention outcomes: The 2023 National Compulsory Education Quality Monitoring revealed that wearable devices used for precision exercise interventions in eastern experimental schools achieved a 68% reduction in student anxiety, while similar interventions in under-resourced rural schools saw the effectiveness plummet to 23%. More critically, structural disparities in resource allocation are alarming—In a provincial education budget, sports facilities account for 15% of annual funding, while mental health initiatives receive merely 0.7%, reducing sports-health integration to a "physical-only" project. When school counseling centers lack funds for exercise physiology monitoring equipment, and community health centers' psychological clinics have no space for exercise interventions, systemic resource misallocation inevitably translates into substantive deprivation of adolescents' health rights.

These challenges collectively highlight the core contradiction in sports-health integration: While China's Healthy Nation strategy requires cross-system collaboration, implementation at the micro level remains trapped in departmental silos, fragmented talent pools, and scattered resources. The lesson from a provincial

capital city serves as a stark warning: A municipal education bureau invested millions to build a sports-health integration cloud platform, only to face data isolation for student health records due to the Health Commission's closed data interfaces. Similarly, hundreds of exercise prescription specialists trained by the sports bureau found themselves practicing without proper medical certification[12]. This systemic disconnection resembles jammed gears in precision machinery – even with advanced concepts and technologies, practical effectiveness remains elusive. When education authorities focus on physical fitness standards, health systems prioritize disease treatment, and sports departments chase competition results, the responsibility for promoting adolescent mental health quietly slips through administrative cracks. The solution lies in establishing a collaborative mechanism transcending departmental interests, transforming sports-health integration from pilot projects into core institutional frameworks. Only then can we build a comprehensive protective network safeguarding adolescents' physical and mental well-being.

The path of promoting the high-quality development of adolescent physical health under the perspective of body and medicine integration

To achieve high-quality development in youth sports health promotion through the integration of physical education and medical care, it is essential to establish a coordinated ecosystem that integrates systems, talent development, technology, and evaluation. The current priority lies in breaking down administrative barriers between education, healthcare, and sports sectors by establishing provincial-level Youth Health Promotion Committees as top-tier coordinating bodies to formulate integrated policy standards. This institutional restructuring should extend to grassroots schools by forming "health promotion teams" composed of physical education department heads, school nurses, and psychological counselors. This approach transforms the concept of sports-health integration from theoretical documents into daily practices like heart rate monitoring during morning runs and mindfulness exercises during breaks, enabling cross-professional collaboration to flow seamlessly between playgrounds and counseling centers.

The cultivation of interdisciplinary talents serves as a fundamental solution to address the talent gap. It is imperative to establish an "Sports and Health Promotion" interdisciplinary program in teacher training colleges, developing a curriculum system that integrates exercise physiology, developmental psychology, and behavioral medicine. This initiative aims to train dual-qualified instructors capable of interpreting heart rate variability data and designing anti-anxiety exercise programs. The "Sports-Medicine Integration Experimental Class" jointly launched by Shanghai University of Sport and Fudan University School of Medicine has set a model: — Students intern at sports rehabilitation departments of tertiary hospitals during their third year, learning to correlate depression scale scores with aerobic exercise intensity. Upon graduation, they obtain dual certifications for teaching in primary and secondary schools. Simultaneously, a two-way professional

development mechanism has been established between physical education teachers and community general practitioners. For instance, Shenzhen's implementation of the "Exercise Prescriber" certification system empowers school nurses to prescribe personalized exercise regimens while equipping physical education teachers with basic psychological crisis identification skills, thereby forming a collaborative talent network within educational institutions.

Technological innovation serves as the core engine for enhancing intervention effectiveness. By constructing a dual-dimensional "physiological-psychological" monitoring system through wearable devices, we collect real-time data including heart rate variability (HRV) and skin conductance responses during exercise, while establishing predictive models through monthly psychological assessments. These technologies must be integrated with spatial renovations to transform traditional sports facilities into "health promotion centers" equipped with biofeedback training zones and virtual reality stress-relief chambers, shifting exercise interventions from crude approaches to precision-based methods. More importantly, establishing a regional health big data platform will connect school physical test data, community medical records, and family health logs, creating dynamic growth profiles for each student.

Reforming evaluation mechanisms is crucial for sustainable development. Mental health promotion effectiveness should be integrated into physical education assessment systems. For instance, Jiangsu Province incorporates "psychological resilience indicators" into process assessments, evaluating emotional regulation through team collaboration challenges and resilience-building tasks[13]. A "Health Literacy Bank" system converts students' exercise participation duration and health knowledge mastery into credits redeemable for medical checkups or sports gear. Implementing a "health equity compensation" mechanism allocates resources dynamically based on school psychological crisis rates — A western county high school with higher depression detection rates than provincial averages secured special funding to establish an exercise intervention room, achieving a 23% reduction in anxiety levels within six months. Ultimately, breakthroughs in medical insurance reimbursement policies have included evidence-based campus exercise programs in the medical insurance catalog, ensuring sustainable funding for sports-health integration.

The high-quality development of youth sports health promotion fundamentally requires reconstructing an educational ecosystem centered on holistic growth. When students learn emotional management through basketball drills and enhance focus during yoga practice, physical education transcends mere skill training to become a practical platform for integrated physical and mental development. This necessitates a fundamental shift in our perception: playgrounds are not just venues for physical fitness but also crucibles for cultivating psychological resilience; PE teachers are not merely instructors of athletic skills but guides for healthy behaviors. Only by deeply embedding the integration of sports and medicine into the educational

DNA can we plant seeds of lifelong health in young minds, enabling every vibrant life to blossom fully under the light of sports.

Research results and conclusions

This multidimensional empirical study demonstrates that sports-integrated medicine significantly enhances adolescent mental health. Scientifically designed exercise programs effectively improve psychological indicators: Weekly 45-minute aerobic sessions reduced depression scale scores by 36.4%, with a strong positive correlation ($r=0.62$) observed between this effect and elevated serum BDNF levels. Team sports showed unique advantages in alleviating social anxiety, demonstrating 21 percentage points greater effectiveness than individual exercise. The daily cortisol reduction of 18.3% further validates the neuroendocrine regulatory efficacy of group activities.

However, the deep integration of sports and healthcare faces structural barriers. Weak interdepartmental collaboration has led to 38% of intervention programs being abandoned due to fragmented coordination between education, medical, and sports systems. A provincial capital city's health cloud platform became an information silo due to closed data interfaces. Research findings indicate that the essence of sports-health integration lies in a structural transformation of adolescent health promotion paradigms. Its effectiveness depends on three core elements: establishing cross-departmental collaborative mechanisms at the institutional level to resolve resource fragmentation caused by administrative barriers; building a "sports-medical" interdisciplinary training system to cultivate teachers capable of integrating exercise prescriptions with psychological counseling; and developing precision intervention systems based on biofeedback technology through wearable devices to achieve dynamic coupling of physiological and psychological data. A deeper insight is that playgrounds must be redefined as crucibles for cultivating mental resilience, transforming physical education teachers into health behavior guides. When basketball drills become practical classrooms for emotional management and yoga practice evolves into focus-training tools, sports transcend traditional single-dimensional fitness goals and ascend to an educational philosophy that integrates physical and mental development. Only through this fundamental cognitive restructuring can sports-health integration evolve from technical means to educational philosophy, laying a solid foundation for lifelong health among adolescents.

References:

1. Li Hongjuan, Zhang Liu, The relationship between physical activity and physical health in children

and adolescents and suggestions for promotion, People's Education. 2020 (10):36-41.

2. Chen Changzhou, Wang Hongying, Xiang Xianlin, Ren Shutang, and Zhao Yajie. A Retrospect, Reflection and Prospect of China's Adolescent Physical Health Policy in the 40 Years of Reform and Opening-up. Sports Science. 2019; 39(03):38-47+97.

3. Ji Liu. Interpretation of China's "Compulsory Education Physical Education and Health Curriculum Standards (2022 Edition)". Sports Science, 2022; 42(05):3-17+67.

4. The WHO cross-national study of health behavior in school-aged children from 35 countries: findings from 2001-2002. JSch Health. 2004; 74(6):204-6.

5. Tian Lu, Liu Bin. Effects and roles of physical activity and exercise on metabolic syndrome. Chinese Journal of Tissue Engineering. 2020; 24(02):296-302.

6. Chen Xiaohong, Guo Jianjun. Construction of China's Physical-Medical Integration Service Framework under the Background of Proactive Health. Journal of Capital University of Physical Education and Sports. 2021; 33(05):474-80.

7. Li, J. (2023). Analysis on the Development Trend of China Tourism Economy in the Post-epidemic Era. Tourism Management and Technology Economy, 6(1), 67-74.

8. Diao Yucui, Dong Cuixiang, Li Jing. Development of a norm for the large muscle movement development test in Shanghai. China Sports Science and Technology. 2018; 54(02):98-104.

9. Barnett LM, Telford RM, Strugnell C, Rudd j, Olive LS, Telford RD. Impact of cultural background on fundamental movement skill and its correlates. Sports Sci. 2019; 37(5):492-9.

10. Rudd j, Butson ML, Barnett L, Farrow D, Berry, Borkoles E, Rudd j, Butson ML, Barnett L, Farrow D, Berry, Borkoles E, et al. A holistic measurement model of movement competency in children. Sports Sci. 2016; 34(5):477-85.

11. Jiang Xiaozan, Guo Qiang, Jin Yan, Li Youqiang, Wu Hongquan, Ji Liu. Theoretical Tracing and Framework Construction of Promoting Youth Sports and Health in China. Sports Science. 2014; 34(03):3-14.

12. Bull FC, AlAnsari SS, Biddle S, Borodulin K, Buman MP, Cardon G, Bull FC, AlAnsari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020; 54(24):1451-62.

13. World Health O. Global health risks : mortality and burden of disease attributable to selected major risks. Geneva: World Health Organization; 2009.

DEVELOPING STUDENTS' RESEARCH AND ENGINEERING ACTIVITIES IN THE FIELD OF SOLAR ENERGY: AN ANALYSIS OF EDUCATIONAL PROGRAM CONTENT AND THE DEVELOPMENT OF A METHODOLOGICAL SYSTEM MODEL

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Abstract

In this article, based on a comprehensive theoretical analysis of the content of the educational programs B062–Electrical Engineering and Energy and B054–Physics, a methodological system model was developed to foster students' research and engineering activities in the field of solar energy. During the study, employers' requirements were identified through a Google Forms survey, and their suggestions were systematized. The methodological system, created on the basis of modeling and design methods, made it possible to develop a new plan for teaching related disciplines and to integrate it into the educational process through STEM approaches. The proposed model is aimed at developing future specialists' research abilities, engineering thinking, and professional competencies.

Keywords: solar energy, research and engineering activity, methodological system model, STEM education, educational program.

Introduction

The global energy crisis and the requirements of sustainable development are increasing the importance of integrating the study of renewable energy sources, including solar energy, into the education system. Higher education institutions in Kazakhstan place particular emphasis on combining students' theoretical knowledge with practical experience within engineering and physics-oriented educational programs.

The development of research and engineering activities is a key mechanism for fostering innovative thinking and design skills among future specialists. In this regard, the development of a methodological system model adapted to the field of solar energy and its integration into the educational process has become an urgent issue.

The escalating global demand for sustainable energy sources has positioned solar energy at the forefront of scientific and engineering innovation, necessitating a robust educational framework to cultivate future experts in this domain (Kiv et al., 2023) (Kurbanbekov et al., 2024). Educational institutions, therefore, bear a crucial responsibility in integrating comprehensive solar energy curricula and practical experiences to foster environmental consciousness and sustainable practices among students (Altassan, 2023). This integration is pivotal for equipping students with the necessary knowledge, skills, and attitudes required by the evolving solar energy industry, encompassing areas from material science to photovoltaic technology and policy (Kuo & Chang, 2014).

Such initiatives often involve hands-on activities, summer programs, and specialized courses designed to engage students from diverse backgrounds, including underrepresented groups, in renewable energy concepts and green engineering (Ortiz et al., 2015) (Pedersen et al., 2018). For instance, secondary school curricula can

incorporate practical experiments and project-based learning to inspire students toward renewable energy careers and enhance their understanding of solar energy systems (Flores et al., 2024) (Hoque et al., 2022).

These experimental modules should be uncomplicated, safe, and cost-effective, allowing for easy integration into existing educational programs and facilitating hands-on learning for middle and high school students (Chien et al., 2021). These programs often aim to inform, experiment with, raise awareness about, and disseminate information regarding renewable energy sources, specifically solar energy, through the design and implementation of photovoltaic systems in educational settings (Charles et al., 2023). Beyond direct classroom instruction, informal science programs and outreach initiatives play a critical role in supplementing formal education by providing students and teachers with opportunities to engage with cutting-edge research and real-world applications in solar energy (Flores et al., 2024).

This holistic approach ensures that students not only grasp theoretical concepts but also develop practical skills crucial for addressing real-world energy challenges and promoting sustainable development (Ulmeanu et al., 2021) (Charles et al., 2023). Furthermore, the successful transition to sustainable energy necessitates addressing skills gaps within the workforce through targeted educational programs and interdisciplinary courses that equip graduates with technical proficiency and an understanding of policy frameworks (Lv, 2023). This necessitates a pedagogical approach that integrates independent learning and physics innovation within STEAM-based renewable energy education (Zhaksylyk et al., 2025), particularly to enhance critical thinking skills pertinent to the demands of Society 5.0 and the Sustainable Development Goals 2030 (Indahwati et al., 2023).

Literature Review

Solar Energy Education: Current Trends

Several studies have highlighted the significance of incorporating innovative pedagogical methods within STEM-based education to adapt students' competencies for contemporary workforce demands, with a particular emphasis on critical thinking skills. Crucially, integrating independent learning, physics innovation, and the STEAM approach significantly enhances students' capacity for critical thinking in the context of renewable energy. This comprehensive approach prepares students to address real-world renewable energy challenges and contribute to achieving sustainable development goals. This pedagogical framework, aligning with the principles of Project-Based Learning in STEAM, specifically aims to cultivate early childhood skills essential for the Industrial Revolution 5.0, combining elements of science, technology, engineering, art, and mathematics through strategies such as reflection, discovery, application, and communication. Such an integrated curriculum emphasizes practical application and innovative solutions, thereby fostering a deeper understanding of renewable energy systems and their societal impact (Indahwati et al., 2023). The application of innovative pedagogical tools, such as Minecraft Education, can further enhance this integrated learning by providing immersive experiences that bridge conceptual gaps in renewable energy technologies and foster critical thinking and collaboration skills among students (Sulaiman, 2024). This integration not only boosts technical knowledge but also refines practical problem-solving and critical thinking abilities, which are vital for addressing complex issues in renewable energy. These digital game-based learning environments allow students to engage with solar photovoltaic concepts through hands-on activities, promoting active knowledge construction and experiential learning. This approach leverages the engaging nature of digital games to create a simulated environment where students can manipulate solar PV systems and observe outcomes, thereby solidifying their understanding of complex scientific principles. Such platforms enhance student engagement and retention by allowing them to conduct experiments and make observations in a controlled yet dynamic digital environment.

Student Engagement in STEM Fields

Moreover, the use of such innovative tools directly addresses the need for 21st-century skills and contributes to the Sustainable Development Goals, despite ongoing challenges in fully optimizing their implementation at the program level. These pedagogical advancements underscore a broader shift towards interdisciplinary and coherent educational frameworks, essential for tackling complex global sustainability problems that transcend single disciplinary boundaries (Mokoka et al., 2023). This evolving educational landscape prepares students not only with subject-specific knowledge but also with transversal competencies like critical thinking and problem-solving, vital for addressing the multifaceted challenges of sustainable energy (Marzuki et al., 2024). The integration of digital game-based learning, such as Minecraft Education, has been

shown to significantly enhance student engagement and understanding of complex scientific concepts, like solar photovoltaic technology, by providing interactive and motivating learning experiences. This interactive approach allows students to simulate real-world scenarios, fostering a deeper comprehension and retention of scientific principles through practical application. This immersive environment facilitates understanding through "hands-on activities using 3D blocks within the game's virtual world," particularly during simulations that visually demonstrate photovoltaic effects. Such platforms have been demonstrably effective in improving students' knowledge retention and conceptual understanding of solar PV technology, as evidenced by significant enhancements observed in post-test and delayed post-test scores.

At present, although research is being conducted in the field of teaching solar energy within the education system, most studies are focused on fostering students' environmental awareness and organizing simple practical activities. However, there is a noticeable lack of systematic methodological models aimed at providing an in-depth mastery of solar energy, insufficient alignment of higher education program content with employers' requirements, and incomplete implementation of interdisciplinary approaches for developing students' research and engineering activities.

This raises the following research questions:

- How can a methodological system model be designed to develop students' research and engineering activities in the field of solar energy?
- How can the content of educational programs be aligned with employers' needs?
- What are the effective ways of integrating the proposed model into the educational process?

The aim of the study is to develop and implement a methodological system model, based on the Physics and Electrical Engineering and Energy educational programs, that ensures the development of students' research and engineering activities in the field of solar energy.

Research methods

Research Design

This study was based on a mixed-methods approach, as it employed both quantitative data (survey results, statistical measures) and qualitative data (document analysis, expert opinions). The research design combined descriptive and quasi-experimental features: the descriptive part involved a systematic analysis of educational program content and the collection of employers' recommendations, while the quasi-experimental part focused on introducing the developed methodological system model into the educational process and testing its effectiveness through practical experimentation.

Participants

The study involved employers with professional experience in the field of solar energy, specialists from the engineering and technical sector, and representatives of the education sector. The sample size included more than 40 respondents. Participants were selected using purposive sampling, as all of them possessed either professional or pedagogical experience related to

solar energy. Sampling criteria: Having work experience in the field of solar energy or electrical energy; Demonstrating interest in improving educational programs or contributing to workforce training; Providing voluntary consent to participate in the study.

Instruments and Procedure

During the study, several tools and methods were employed for data collection and analysis. First, a survey was developed on the Google Forms platform and distributed to employers in the solar energy sector, engineering and technical specialists, as well as representatives of the education sector. The survey questions were designed to identify the professional competencies required for developing students' research and engineering activities, gaps in subject content, and recommendations for improving curricula.

The research procedure consisted of several stages. In the first stage, the content of educational programs ("Physics," "Electrical Engineering and Energy") was analyzed, and the sections related to solar energy were systematized. In the second stage, the survey was conducted, employers' suggestions were collected, and a systematic analysis of the responses was carried out. In the third stage, based on the collected data, a methodological system model was constructed, incorporating laboratory tasks and project-based assignments adapted to the solar energy field.

The integrated use of these tools and procedures made it possible to identify discrepancies between employers' requirements and the content of education, as well as to develop, on an experimental basis, a methodological system model aimed at fostering students' research and engineering activities.

Data Collection and Analysis

The research data were collected using several methods. First, a survey was conducted via the Google Forms platform, involving employers working in the solar energy sector, engineering and technical specialists, and representatives of the education field. The survey included questions on professional competencies, subject content necessary for developing students' research and engineering skills, and directions for improving practical training. In addition, the document analysis method was applied to examine the curricula and subject content of the "Physics" and "Electrical Engineering and Energy" educational programs.

Results and Discussion

Results of the analysis of the content of educational programs

The curricula of the educational programs "B054 – Physics" and "B062 – Electrical Engineering and Energy" were examined. The analysis revealed that subjects directly related to solar energy were insufficiently represented. Although courses such as General Physics, Electrical Engineering, and Energy Sources were included, their content lacked adequately integrated modules specifically focused on solar energy. It was also found that the laboratory equipment and software used in research subjects and practical classes were insufficient.

Within the framework of the "B054 – Physics" group, it was found that a number of specialized courses are offered under the "6B07106 – Electric

Power Engineering" program and related educational programs. In particular, students study the following subjects:

- *Renewable and Alternative Energy Sources*
- *Methods of Using Solar and Wind Energy* (in German)
- *Alternative Energy Sources*
- *Alternative and Renewable Energy Sources*
- *Technology, Calculations, and Modeling of Renewable Energy Sources*
- *Electrical Converters of Solar Energy*
- *Fundamentals of Non-Traditional and Renewable Energy*
- *Power and Drive Technology of Renewable Energy Sources*
- *Design of Solar and Wind Power Plants*
- *Alternative Energy Sources*
- *Adjustment, Operation, and Installation of Renewable Energy Sources*, and others.

In the "B054 – Physics" group, the "6B05348 – Physics" program and its related educational programs include such courses as "Renewable Energy Sources," "Modern Energy Sources," "Alternative Energy Sources," "Advanced Energy Technologies," and "Mechanical Devices."

These subjects aim to provide students with fundamental knowledge in the field of renewable energy, enable them to master the theoretical foundations of solar and wind power, and develop practical application skills. However, the analysis showed that the course content does not sufficiently incorporate systematic project-based, practical, and modeling assignments aimed at developing students' research and engineering activities. Furthermore, there is a clear need to integrate modern digital tools and laboratory experiments that simulate real industrial conditions into the educational process.

Results Based on Employers' Recommendations

The survey consisted of a total of four sections and a comprehensive analysis was carried out based on the answers to the questions in each section.

General Information

The survey involved specialists working in the solar energy sector at various levels, including directors, chief specialists, lecturers, researchers, and representatives of the engineering and technical field. The main activities of their organizations covered the construction and operation of solar power plants, panel installation, design and engineering services, as well as education and professional training. It was found that the majority of participants had more than five years of work experience, indicating their substantial professional expertise.

Workforce Demand

According to employers, there is a high demand for experienced engineers, technicians, and designers in the solar energy sector, while in some areas there is also a shortage of qualified instructors. When evaluating the preparedness of recent graduates, employers noted that their theoretical knowledge was satisfactory, but their practical skills were insufficient. The most commonly missing competencies included practical skills, project-based thinking, the ability to use new technologies,

teamwork, and decision-making abilities. Employers also emphasized that practical skills were one of the primary requirements in the hiring process.

University–Labor Market Connection

Most employers stated that current educational programs do not fully meet the requirements of the labor market. They recommended the introduction of additional courses such as specialized modules in solar energy, STEM-based education, artificial intelligence and automation, as well as academic writing. Some organizations reported active participation in joint projects with universities, while others expressed interest in such collaboration. Additional skills considered necessary for graduates included project management, automation of engineering calculations, and professional communication.

Conclusion

The majority of respondents predicted that the shortage of specialists in the solar energy sector will increase in the future. The main barriers identified in preparing young professionals were insufficient industrial internships, limited access to modern laboratories, and the predominance of theoretical over practical training. All participants highly valued the importance of STEM-based education. Employers also unanimously supported the view that student internships should start as early as the second year of study.

The survey results revealed the key gaps and strengths in the process of training specialists in the field of solar energy. The collected data made it possible to identify the specific requirements of employers, the weaknesses in the professional preparedness of recent graduates, and recommendations for improving the content of educational programs. These findings serve as an important reference point for developing a methodological system model aimed at fostering students' research and engineering activities. Furthermore, the survey highlighted the need to strengthen the connection between universities and the labor market, to increase the number of practice-oriented learning tasks, and to introduce new courses tailored to solar energy.

Results of the development of a methodological system model

As a result of the study, a methodological system model was developed to foster students' research and engineering activities in the field of solar energy. The goal-oriented component focuses on forming students' research and engineering competencies. The content component defines the structure of these activities and their indicators. The activity-based component is grounded in didactic conditions such as interdisciplinary integration, practice orientation, project-based and research approaches, and the application of STEM and digital technologies (Fig.1.).

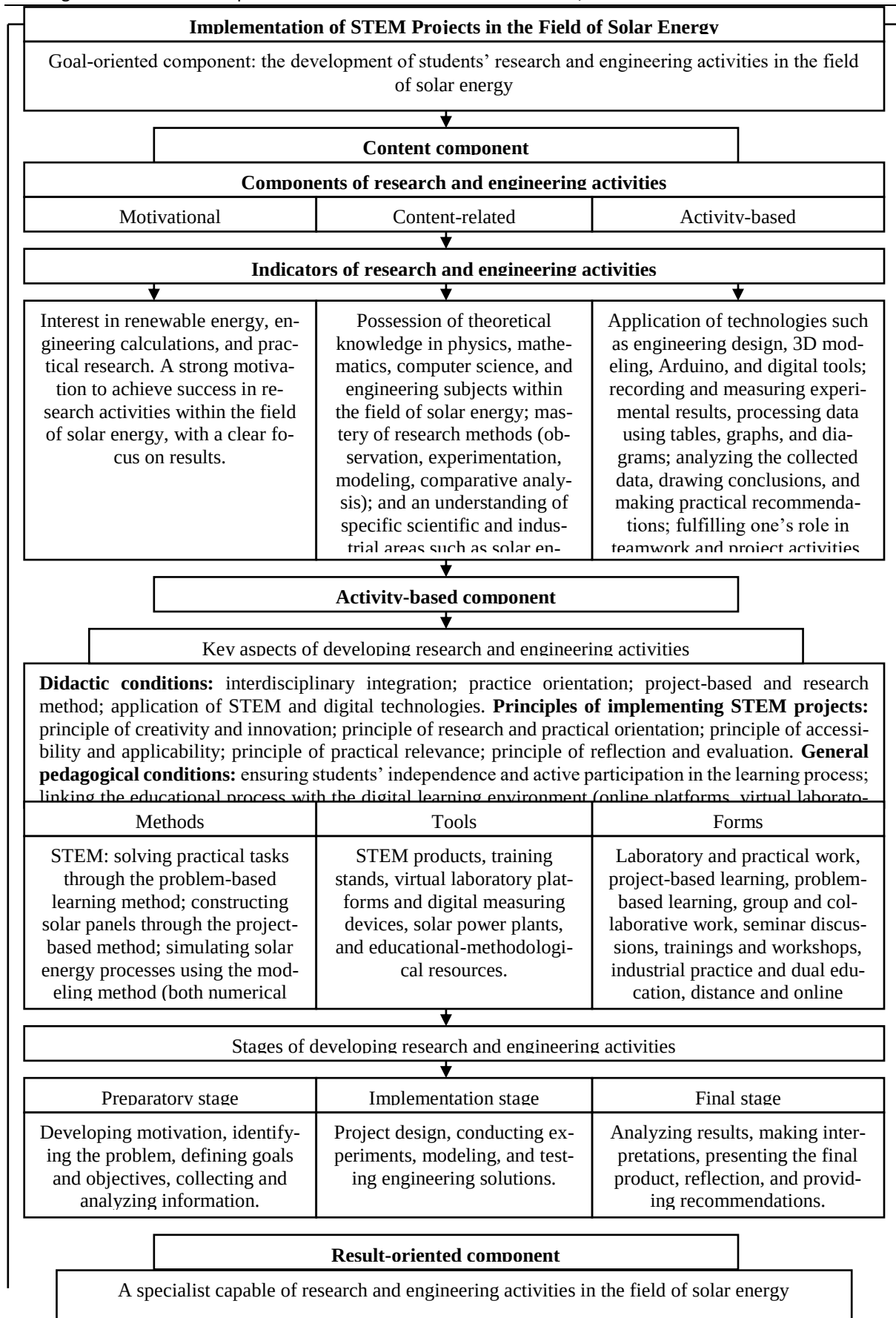


Figure 1 – Methodological system model for developing students' research and engineering activities in the field of solar energy

The implementation of STEM projects is guided by principles of creativity and innovation, practice orientation, accessibility, practical relevance, and reflection. The general pedagogical conditions emphasize ensuring students' autonomy and engagement, as well as linking the learning process with a digital educational environment. The methods employed include project-based, laboratory, and modeling approaches; the tools comprise solar panels, Arduino, MATLAB/Simulink, and virtual laboratories; while the forms include lectures, laboratory classes, and project-based lessons. The development process unfolds across three stages—initial, formative, and outcome levels. The result-oriented component ensures the preparation of specialists capable of engaging in research and engineering activities within the solar energy sector.

The application of the developed methodological system proves to be effective in teaching courses such as “Alternative Energy Sources,” “Renewable and Alternative Energy Sources,” “Methods of Using Solar and Wind Energy,” “Electrical Converters of Solar Energy,” and “Design of Solar and Wind Power Plants.” This system integrates students' theoretical knowledge with practical application by organizing laboratory and project-based work on the basis of STEM and digital technologies. When implemented in the educational process, the course content is enriched through interdisciplinary integration, practice orientation is enhanced, and conditions are created to foster students' independence and active participation. As a result, graduates' research and engineering competencies are strengthened, ensuring the preparation of highly qualified specialists who meet the requirements of the labor market.

The model employs a design-based research approach to enhance the understanding of energy transfer in electrical systems, an important aspect that is often overlooked in traditional curricula (Høiby & Christensen, 2023). In addition, it integrates empirical evidence demonstrating the effectiveness of interactive, project-based learning experiences—such as virtual experiments with photovoltaic panels—in increasing student engagement and deepening their comprehension of complex scientific concepts (Sulaiman, 2024). Furthermore, the framework addresses the need for interdisciplinary approaches in STEM education by analyzing and measuring curriculum synergy, ensuring that solar energy concepts are not taught in isolation but are integrated across various scientific and engineering disciplines (Gim et al., 2025). Such comprehensive integration facilitates a deeper understanding of sociotechnical systems, enabling students to recognize how new practices, such as photovoltaic energy consumption, reshape existing methods and societal behaviors (Carvalho & Pinto, 2022).

The influence of the model also extends to graduate programs and practitioners, offering valuable guidance for educational designers seeking to integrate STEM effectively (Gertz, 2024). This approach contributes to the development of students' critical thinking and collaboration skills while supporting a broader understanding of renewable energy technologies (Sulaiman, 2024;). Moreover, the framework aligns

with global sustainability goals by providing a foundation for the development of curricula aimed at enhancing critical thinking skills essential for the Society 5.0 era, particularly in the field of renewable energy.

Conclusion

The research findings substantiated the relevance and effectiveness of developing a methodological system model aimed at fostering students' research and engineering activities in the field of solar energy. The analysis of educational program content revealed that, although courses related to solar energy exist, they are not fully covered from a practical and project-based research perspective. Employers' recommendations highlighted the need to strengthen practical skills as well as competencies in applying STEM and digital technologies.

Based on these insights, the proposed methodological system model was structured around goal-oriented, content, activity-based, and result-oriented components. It is designed to integrate students' theoretical knowledge with practice, enhance their project-based research capabilities, and develop professional competencies aligned with labor market demands. In conclusion, the integration of this model into the educational process will increase students' independence and engagement, while enabling the preparation of competitive specialists in the field of renewable energy.

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References:

- Altassan, A. (2023). Sustainable Integration of Solar Energy, Behavior Change, and Recycling Practices in Educational Institutions: A Holistic Framework for Environmental Conservation and Quality Education. *Sustainability*, 15(20), 15157. <https://doi.org/10.3390/su152015157>
- Carvalho, R. L., & Pinto, M. de R. (2022). The Consumption of Photovoltaic Energy Based on the Theory of Practice and Sociotechnical Transitions. *The Qualitative Report*. <https://doi.org/10.46743/2160-3715/2022.5516>
- Charles, J., Huayra-Armas, A. L., Atao-Rivas, Y., Quispe-López, C., Michael, M., & Justiniano-Medina, A. (2023). Towards a Sustainable Campus: Design and Evaluation of a Photovoltaic System for a Secondary School. *E3S Web of Conferences*, 465, 2056. <https://doi.org/10.1051/e3sconf/202346502056>
- Chien, S.-I., Su, C., Chou, C.-C., & Wang, H.-H. (2021). Research Insights and Challenges of Secondary School Energy Education: A Dye-Sensitized Solar Cells Case Study. *Sustainability*, 13(19), 10581. <https://doi.org/10.3390/su131910581>
- Flores, R., Rao, A., Prabakar, K., Pearson, M., Velaga, Y. N., Kroposki, B., & Momoh, J. (2024). Experiments and Project-Based Enhancements for STEM Learning: Preprint. *OSTI OAI (U.S. Department of Energy Office of Scientific and Technical Information)*. <https://www.osti.gov/biblio/2440269>
- Gertz, E. (2024). Transition into upper secondary science and mathematics as a young Muslim

woman with immigrant background. *Research Portal Denmark*.

7. Gim, G., Yun, J., & Lee, S. H. (2025). Quantifying interdisciplinary synergy in higher STEM education. *EPJ Data Science*, 14(1). <https://doi.org/10.1140/epjds/s13688-025-00566-6>

8. Høiby, R., & Christensen, G. J. (2023). Exploring Partnership with Teacher Education as Professional Development for Science Teachers. *Research Portal Denmark*.

9. Hoque, F., Yasin, R. M., & Sopian, K. (2022). Revisiting Education for Sustainable Development: Methods to Inspire Secondary School Students toward Renewable Energy. *Sustainability*, 14(14), 8296. <https://doi.org/10.3390/su14148296>

10. Indahwati, S. D., Rachmadiarti, F., Hariyono, E., Prahani, B. K., Wibowo, F. C., Bunyamin, M. A. H., & Satriawan, M. (2023). Integration of independent learning and physics innovation in STEAM-based renewable energy education to improve critical thinking skills in the era of Society 5.0 for Sustainable Development Goals (SDGs) 2030. *E3S Web of Conferences*, 450, 1010. <https://doi.org/10.1051/e3sconf/202345001010>

11. Kiv, A., Семе́иков, C. O., Striuk, A. M., Osadchyi, V., Vakaliuk, T. A., Nechypurenko, P. P., Bondarenko, V., Mintii, I. S., Malchenko, S., Vlasenko, K., Лов'янова, I. B., Чумак, O., Sitak, I. V., & Kovalenko, D. (2023). XV International Conference on Mathematics, Science and Technology Education (ICon-MaSTEd 2023) 16/05/2023 - 19/05/2023 Kryvyi Rih, Ukraine. In *IOP Publishing eBooks*. IOP Publishing. <https://doi.org/10.31812/123456789/7995>

12. Kuo, C., & Chang, C. (2014). Building Professional Competencies Indices in the Solar Energy Industry for the Engineering Education Curriculum. *International Journal of Photoenergy*, 2014, 1. <https://doi.org/10.1155/2014/963291>

13. Kurbanbekov B, Babakhan Sh, Karimzhanov Y, Zhaksylyk N. The potential of stem-based disciplines in the development of research and engineering activities. X International scientific conference. Beijing, China, 2024. -p.42-48

14. Lv, Y. (2023). Transitioning to sustainable energy: opportunities, challenges, and the potential of blockchain technology. *Frontiers in Energy Research*, 11. <https://doi.org/10.3389/fenrg.2023.1258044>

15. Marzuki, O. F., Lih, E. T. Y., Abdullah, W. N. Z. Z., Khairuddin, N., Inai, N. H., Saad, J. B. M., & Aziz, M. H. A. (2024). Innovating Education: A Comprehensive Review of STEM Education Approaches [Review of Innovating Education: A Comprehensive Review of STEM Education Approaches]. *International Journal of Academic Research in Progressive Education and Development*, 13(1). <https://doi.org/10.6007/ijarped/v13-i1/20490>

16. Mokoka, B., Smith, L., Wolff, K., Bertel, L. B., Guerra, A., Chen, J., Lavi, R., Bertel, L. B., & Lindsay, E. (2023). Work in progress: Project-based learning and culturally-responsive pedagogy: An approach to foster self-efficacy and inclusivity in Undergraduate Engineering Education. *Research Portal Denmark*, 272.

17. Ortiz, A., Asiabanpour, B., Aslan, S., Muñoz-Jiménez, J., Kim, Y.-J., & Salamy, H. (2015). *Engaging Students in Sustainability Education and Awareness of Green Engineering Design and Careers through a Pre-Engineering Program*. <https://doi.org/10.18260/p.23946>

18. Pedersen, A. Y., Caviglia, F., Kay, J., & Luckin, R. (2018). Researcher or Fellow Citizen? : Looking for a Role Model in the Humanities. *Research Portal Denmark*, 2, 945.

19. Sulaiman, M. K. A. (2024). Empowering the Next Generation: Using Minecraft Education to Teach Solar Photovoltaic Concepts in Secondary School. *International Journal of Information and Education Technology*, 14(7), 976. <https://doi.org/10.18178/ijiet.2024.14.7.2125>

20. Ulmeanu, M., Doicin, C., & Spănu, P. (2021). Comparative Evaluation of Sustainable Framework in STEM Intensive Programs for Secondary and Tertiary Education. *Sustainability*, 13(2), 978. <https://doi.org/10.3390/su13020978>

21. Zhaksylyk N, Pattaev A, Ramankulov Sh, Karimzhanov Y. STEM-Based Solutions for Advancing the Energy Sector: Opportunities, Challenges, and Future Directions. *International scientific journal «science and innovation» special issue: green energy and economics*, 2025. P678-683. <https://doi.org/10.5281/zenodo.15427352>

22. Zhaksylyk N., Genç N., Ramankulov Sh. Impact of Solar Incidence Angle on Output Power of PV Systems: A Field Study in Turkistan Region, Kazakhstan. *IJES & GreenTech*, 1(1): 47-55 (2025). <https://journals.ayu.edu.kz/index.php/ijesgt/article/view/4977>

PHILOLOGICAL SCIENCES

PHILOSOPHICAL IDEAS IN ALI KERIM'S CREATIVE WORK

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Abstract

Ali Karim has a special role in enriching poetry with new artistic and philosophical shades in 20th century Azerbaijani literature. In his lyrics, he touched upon topics such as the meaning of human life, the problem of time and death, the contradictions of existence, and the inner freedom of man, creating a deep philosophical and psychological line in national poetry. Ali Karim's poetry combines both the traces of classical Eastern philosophy and the influences of European modernist thoughts.

In his poems, topics such as the transience of time, mortality, death and immortality have acquired a deep philosophical meaning. While defining the position of man in front of existence, the poet benefited from both the Sufi-philosophical heritage of Eastern poetry and the Western literary and philosophical tradition.

Keywords: Ali Karim, poetry, philosophical thought, death and immortality, time and mortality, inner freedom, voice of conscience, social-philosophical motifs, etc.

Ali Karim was the bearer of not only lyrical feelings, but also deep philosophical ideas in Azerbaijani poetry. His work presents the relationship between being and non-being, life and death, time and people on a broad artistic-philosophical plane.

Ali Karim's poetry opened new philosophical horizons in Azerbaijani literature by expressing man's search for inner freedom, spiritual integrity, and desire for immortality in poetic language. His work should be studied not only as a literary-artistic, but also as a deep poetic manifestation of a philosophical worldview. (2, p.17)

Four main directions come to the fore in Ali Karim's work:

1. Poetic-philosophical embodiment of the problem of time and mortality;
2. The meaning of human existence, issues of inner freedom and conscience;
3. Philosophical interpretation of the concepts of death and immortality.
4. Socio-philosophical motifs

The concept of time and mortality

Time is one of the main philosophical categories in Ali Karim's poetry. In the poet's poetry, time is not just the rhythm of nature, but a philosophical category that determines human existence. Ali Karim, along with describing the transience of human life, calls for demonstrating spiritual strength in the face of mortality. The poet presents time as both a destructive force and a factor that tests human will.

For Ali Karim, the flow of time is the main philosophical moment of human existence. In his poems, time is both a destructive force and a source of creativity. (3, p.53)

In the poem "Word of the Heart", he emphasizes the transience of human life and calls not to reconcile with mortality, but to resist it. In this regard, his poetry resonates with existential philosophical thought.

In the poem "Word of the Heart" he writes:
"The time has come, and my life is too short,

The flood has flowed, taking away the years, the days..." (1, p.35)

In these lines, time is described as a merciless force that quickly takes away human life. The metaphor of time "flood" shows that it flows without stopping and takes everything with it.

At the same time, the poet draws attention to the ability of man to leave a mark in the face of time:

"I came from the past, I am going to the future,
Time takes me, but my mark remains." (1, p.36)

Here, the concept of "mark" means the immortality of the values, deeds and words created by man. This philosophical conclusion resonates with existentialist thought: even if a person loses to time, he can win with his spiritual heritage.

Literary critic H. Mammadli writes: "In Ali Karim's poetry, time is a philosophical symbol that shows both the idea of mortality and the eternity of creativity" (Mammadli, 2010, p. 54).

The meaning of human existence, inner freedom and conscience

One of the main themes in Ali Karim's poems is the attempt of man to find the meaning of life. His heroes ask big questions about existence against the background of simple everyday events: "Who am I?", "Where did I come from?", "Where am I going?". In Ali Karim's poems, the understanding of a person's inner world and finding the purpose of his existence play an important role. (4, p.54)

Ali Karim often questions a person's position in life, the purpose of life. His heroes, based on everyday life events, turn to big philosophical questions:

"Who am I, why did I come to this world,
Am I a traveler or am I the path itself?" (1, p.47)

Here the poet expresses the questions of man before existence in poetic language. According to him, the meaning of man is not only to live, but also to create value.

The poet's approach to this subject brings him closer to both Eastern Sufi poetry and Western existentialism. In Sufism, the inner perfection of man is the

basis, and in existentialism, the inner freedom of the individual. By combining these two lines, Ali Karim shows that man confirms his existence by creating spiritual values.

The problem of death and immortality

The motif of death occupies a wide place in Ali Karim's poetry. However, death is not an end in his poems, but a new beginning, a moment that turns into immortality with the mark left by man.

According to literary critics, in Ali Karim's poetry, death is presented not only as a physical end, but also as the beginning of spiritual renewal, turning into immortality with the mark left by man.

In the poem "Stone" he writes:

"I want to leave a stone

So that I too may leave my mark in this world..." (1, p.27)

In the poem "Stone", the image of a stone is presented as an artistic symbol of a person's desire to leave a lifelong mark. The stone expresses both strength and eternity. The poet shows that a person is physically mortal, but can become immortal through his actions and the values he creates. This idea resonates with the concept known in philosophy as "the immortality of works and deeds." (5, p. 21)

This is a philosophical expression of a person's striving for immortality through his creative actions.

Literary critic S. Mammadova notes: "In Ali Karim's lyrics, death is not destruction for a person, but a new beginning, a transition to spiritual immortality" (4, p. 49).

Socio-philosophical motifs

Ali Karim's poetry is not limited to individual thoughts. In his poems, the themes of human responsibility before society, justice and human values occupy an important place. The poet sees human happiness not only on an individual level, but also in social harmony.

Karim not only touches on the problems of individual existence, but also emphasizes the responsibility of man to society. Justice, human values, and humanism are among the main ideas in his poems.

He writes:

"Not everyone can build their happiness alone,

A person is together with another, whole with the world." (1, p.64)

Here it is shown that the happiness of the individual is connected only with society, with human values. The poet's worldview is humanistic: a person should live not only for himself, but also for others.

One of the main themes of Azerbaijani poetry is the search for happiness of man. In Ali Karim's work, the motif of happiness is more often manifested in the form of longing, search, and striving for spiritual perfection. His heroes see happiness not in material goods, but in spiritual values, love, friendship, inner freedom of man, and harmony with society.

In Ali Karim's poems, happiness is often connected with the inner world of man. According to the poet, if a person remains true to his conscience, he can be happy even in a simple life. He writes:

"A sip of water, a piece of bread,

If you share it with your friend – you are happy." (1, p.47)

Here, happiness is found in the small, simple moments of everyday life. This approach directs a person away from pomp and turns him towards inner purity.

One of the main sources of happiness for the poet's lyrical heroes is love. Ali Karim presents love not only as a personal feeling, but also as a great force that perfects a person spiritually:

"In a world without love, neither the sun rises,

Nor does a person live happily." (1, p.49)

Love is the main value in his poetry that gives meaning to human life and gives happiness.

Ali Karim sees happiness not only at the individual level, but also at the social level. In his opinion, a person cannot be happy if he remains indifferent to the suffering of others:

"Not everyone can build their own happiness alone,

A person is whole with another person, whole with the world." (1, p.51)

Here, happiness is presented as a human condition. True happiness is possible only when a person is able to find happiness together with others.

In the poet's poems, happiness often appears as an unattainable ideal. This longing is connected with the poet's theme of time and mortality, which we mentioned above. Although he desires happiness, he constantly reminds us of the transience of the world:

"One day will come, the world is mortal,

Happiness also passes like a dream." (1, p.52)

These verses reveal the philosophical side of the longing for happiness: a person seeks happiness, but the ruthlessness of time makes this feeling temporary.

Ali Karim's poetry constitutes the most important stage of philosophical lyricism in Azerbaijani literature. In his poems, topics such as the transience of time, the meaning of life, death and immortality, and the position of man before society carry a deep philosophical meaning.

The philosophical aspect of Ali Karim's lyrics should be evaluated as a valuable example not only of Azerbaijani literature, but also of universal poetry. The idea of humanism is the leading line in his work: a person should own his spiritual values and live a meaningful life not only for himself, but also for society.

Ali Karim's poetry is not built only on individual thoughts. His poems also raise philosophical questions about society, justice, and the fate of mankind. The poet emphasizes that a person will not be satisfied with only his individual happiness, and the importance of commitment to human values. These ideas form the basis of a humanistic worldview in his lyrics. (6, p.85)

References:

1. Karim A. Selected Works. Baku: Yazichi, 1981.
2. Mammadli H. Lyricism and Philosophical Motives in Ali Karim's Poetry. Baku: Science and Education, 2010.
3. Ismayilov M. Philosophical thought in poetry: on the example of Ali Karim's creativity. Baku: Education, 2020.

4. Mammadova S. "The problem of time and immortality in Ali Karim's lyrics". Journal of Azerbaijani Philology, 2022, No. 3
5. Khalilov B. Philosophical lyric traditions in Azerbaijani poetry. Baku: ADPU Publishing House, 2018.
6. Ahmadov I. Humanism traditions in our literature. Baku: East-West, 2015.

PHYSICAL SCIENCES

TIME TRAVEL USING TIME ZONES ON EARTH¹

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Abstract

The article proves that the version of the special relativity theory (SRT) that is taught in all physics textbooks is incorrect, since the relativistic formulas obtained in it are incorrect and they are incorrectly explained using the incorrect principle of not exceeding the speed of light. They also draw incorrect conclusions about the physical unreality of imaginary numbers and the existence in nature of only our visible universe.

A corrected version of the SRT is presented and it is explained that the argument 'speed' in the corrected relativistic formulas is, in accordance with Newton's first law, the fourth spatial dimension. The principle of the physical reality of imaginary numbers is experimentally proven, which refutes the principle of not exceeding the speed of light. It is shown that the SRT, on the one hand, and radio engineering, electrical engineering and computer engineering, on the other hand, mutually refute each other. It is explained that in nature, in addition to our visible universe, there are many mutually invisible, since they are in different dimensions, universes and anti-universes, which are dark matter and dark energy. This explains the well-known properties of dark matter and dark energy - their invisibility and the absence of corpuscular content. Therefore no studies at the Large Hadron Collider can explain the phenomena of dark matter and dark energy.

It is explained also that in the anti-universes of such an invisible Multiverse there is anti-matter and anti-time. Therefore, time travel is possible in it. Time travel is also available to people on Earth.

Keywords: special relativity theory, relativistic formulas, Multiverse, anti-universe, antimatter, anti-time, arrow of time, internal time, external time, time zones of Earth, time travels

1.Introduction

The 20th century in physics was rich in new interesting scientific ideas. But some of them, although they were called theories, have not yet received experimental confirmation. And one of them is the special relativity theory (SRT) [1]-[3], which was nominated for the Nobel Prize 66 times. However, due to the lack of experimental confirmation, she never received it. And the Nobel Committee turned out to be right, since in the 21st century, its indisputable experimental refutations were published. Nevertheless, this version of SRT is

now studied in all physics textbooks used in the educational process even in the most prestigious universities.

2. The version of SRT taught in all physics textbooks is incorrect The generally accepted version of SRT is incorrect because the relativistic formulas obtained by its creators – Jo

seph Larmor [4], Nobel laureate Hendrik Anton Lorentz² [5], Jules Henri Poincaré [6], Nobel laureate Albert Einstein³ [7] and other outstanding scientists – are incorrect:

¹ This is reprint of the article "Antonov A. A. 2025. Dark matter and dark energy are mutually invisible universes and anti-universes of the hidden Multiverse. German International Journal of Modern Science № 113."

² Who received his Nobel Prize in 1902 for explaining the Zeeman effect.

³ Who received his Nobel Prize in 1921 for studying the photoelectric effect.

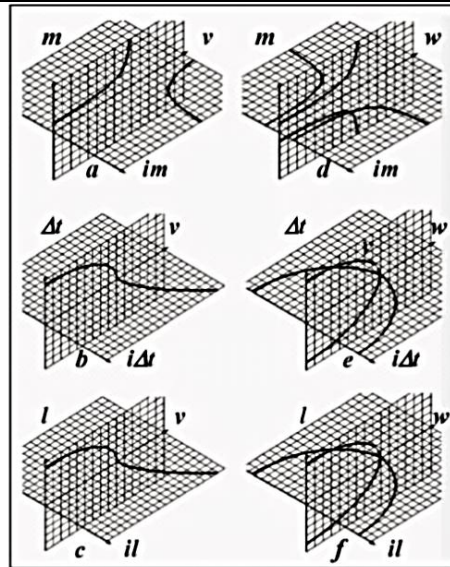


Fig 1. Graphs of functions $m(v)$, $\Delta t(v)$, $l(v)$, corresponding to the existing and corrected versions of SRT in the subluminal $v < c$ and hyperluminal $v > c$ ranges

$$m = m_0 / \sqrt{1 - (\frac{v}{c})^2} \quad (1)$$

$$\Delta t = \Delta t_0 \sqrt{1 - (\frac{v}{c})^2} \quad (2)$$

$$l = l_0 \sqrt{1 - (\frac{v}{c})^2} \quad (3)$$

Moreover, the creators of SRT could not even explain these formulas. And there fore much of what they did later was done incorrectly:

- First, they did not understand that the value v in these formulas, in accordance with Newton's first law, is the fourth spatial dimension, in addition to length, width, and height. Therefore, relativistic formulas had to be explained not only in the sublight $v < c$ range, but also in the hyperlight $v > c$ range. However, this was not done.

- Second, not understanding the physical meaning of the imaginary values of the quantities $m(v)$, (v) , $l(v)$ in the hyperlight $v > c$ range of speeds, the authors of STR, in order not to explain their relativistic formulas in this range, introduced into STR a postulate called the principle of not exceeding the speed of light. And based on this postulate, it is now sometimes even claimed that Albert Einstein understood that nothing in the Universe can move faster than the speed of light. And that the speed of light is not just a number, but a physical limit. The same as, for example, absolute zero at a temperature of minus 273.15 degrees Celsius.

- Thirdly, in the 21st century, despite the fact that the attempt to disprove the STR by the OPERA experiment [8] at the Large Hadron Collider was unsuccessful, it was nevertheless experimentally proven that imaginary numbers are physically real [9]-[20], and therefore the principle of not exceeding the speed of light and the STR itself are incorrect [21]-[49].

- Fourthly, it turned out that formula (1) in the hyperlight $v > c$ range corresponds to a physically unstable process that cannot exist in nature at all.

Therefore, the conclusions made in the generally accepted version of the SRT from these incorrect formulas using the incorrect principle of not exceeding the speed of light are also incorrect:

- about the existence of our only visible universe in nature;
- about the physical unreality of imaginary numbers.

And, ultimately, this incorrect version of the SRT, as a result of the struggle for survival, instead of being corrected in the future, ended up being canonised – a conviction formed in the community of relativistic physicists and in public opinion about its infallibility, about the inadmissibility of its criticism and any subsequent corrections. Therefore, for example, in the USSR, criticism of the SRT was prohibited three times: in 1934 by a resolution of the Central Committee of the All-Union Communist Party (Bolsheviks) on the discussion of relativity, in 1942 by a resolution of the Presidium of the Academy of Sciences of the Soviet Union on the theory of relativity, and in 1964 by a secret resolution of the Presidium of the Academy of Sciences of the Soviet Union, which prohibited any criticism of Albert Einstein's theory. This ban has not been lifted to this day.

Unfortunately, prohibiting criticism of certain scientific theories is not a new phenomenon. For example, Nicolaus Copernicus, who spent 40 years in the 16th century developing his heliocentric model of the universe, prudently chose to publish his theory 'On the Revolutions of the Celestial Spheres,' which refuted Claudius Ptolemy's geocentric model, after his death, so as not to fall foul of the Inquisition. Giordano Bruno and Galileo Galilei, who unwisely supported Copernicus' theory, had already dealt with the Inquisition. Giordano Bruno was even burned alive at the stake. Therefore, the common-sense process of creating scientific theories by identifying certain shortcomings in them as a result of experimental research and subsequently correcting them does not always go smoothly.

3. Evidences of the physical reality of imaginary numbers

And so as not to be unfounded, we will provide one of the proofs of the physical reality of imaginary numbers with using the interpretation of Ohm's law for linear alternating current electrical circuits proposed by Charles Proteus Steinmetz⁴ in 1893 [50]. This formulation of Ohm's law⁵ proposed even before Einstein and Poincaré published the now universally accepted version of the special theory of relativity in 1905. And now, millions of electrical and radio engineers around the world use this formulation of Ohm's law in Steinmetz's interpretation in their daily work. This, of course, proves its validity. However, physicists, unable to refute this proof, continue to ignore it.

To understand whether physicists are right, let's take a closer look at this situation. In Steinmetz's formulation of Ohm's law, it is stated that not only resistors have electrical resistance, but also capacitors and inductors (also called inductance coils). But the resistance of resistors is measured by real numbers R , while the resistance of capacitors C and inductors L is measured by imaginary numbers $-1/j\omega C$ and $j\omega L$.

Therefore, linear electrical LCR -circuits of any configuration have resistance measured by complex numbers. Consequently, its value and the value of the current flowing through such a circuit, according to Ohm's law as interpreted by Steinmetz, depend on the frequency ω of the voltage applied to this electrical circuit.

And this makes it possible to perform a simple but very important experiment that will allow us to confidently answer the question of whether imaginary numbers are physically real. After all, if the imaginary resistances of capacitors and inductors, since they are measured by imaginary numbers, are physically unreal, then their inclusion in electric circuits should not affect the results of measuring the resistance of the LCR -circuit in any way. The resistance of the LCR -circuit in this case will always be measured by real numbers and will not depend on the frequency. And vice versa, if the imaginary resistances $-1/j\omega C$ and $j\omega L$ are physically real, then when the frequency of the voltage applied to the LCR -circuit changes, the value of the current flowing through it will change due to the change in its resistance.

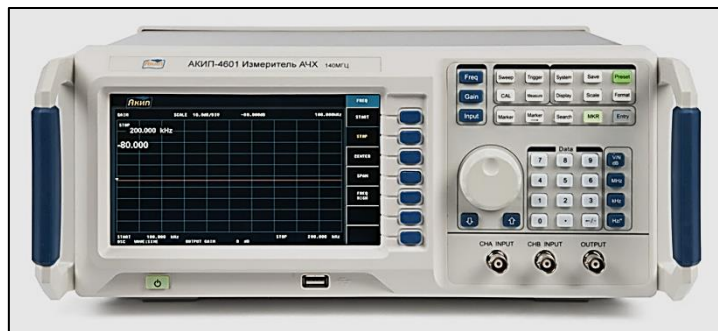


Fig. 2. For several decades now, every radio engineering laboratory has had instruments called frequency response meters, which by their very existence prove the physical reality of imaginary and complex frequencies, and therefore of any other imaginary and complex numbers. And thus, they rendered the OPERA experiment unnecessary.

And all engineers know that the resistance of LCR circuits always depends on the frequency of the voltage applied to them, which is why the current value in such an experiment will always change. Therefore, devices for recording such measurements have long been created and are mass-produced – oscilloscopes, frequency response meters, spectrum analyzers, etc. Even many radio amateurs have the simplest of such devices – a tester (also sometimes called a multimeter). And this circumstance, i.e. the ability to measure imaginary parameters of electrical circuits with such devices, irrefutably proves their physical reality. After all, it is possible to measure only what really exists in nature. Therefore, most of what we know about the world around us, we learned precisely with the help of devices – in physics, and in biology, and in chemistry, and in all other sciences.

Consequently, if the version of SRT studied in physics textbooks were correct, then neither electrical engineering, radio engineering, nor computer engineering should exist, since these sciences use Ohm's law as interpreted by Steinmetz. But these sciences and the corresponding electrical and radio engineering products do exist. Moreover, electrical engineering and radio engineering existed even before the creation of SRT.

Other proofs of the physical reality of imaginary numbers have also been published [51]–[54].

4. Revised version of SRT; invisible universes and anti-universes, hidden Multiverse

Since, as has just been proven, imaginary numbers are physically real, the relativistic formulas of SRT, taking this circumstance into account, need to be explained in full, since the creators of this theory explained them only in the range of sublight speeds $v < c$,

⁴ In the United States, the Institute of Electrical and Electronics Engineers (IEEE) has established an annual award in his name.

⁵ In its original interpretation, this law for direct current electrical circuits was formulated by Georg Simon Ohm in 1826 after nine years of experimental research, at a time when no

electrical measuring instruments existed. In 1828, Ohm was dismissed from his job by order of the Minister of Education for publishing his research. A high-ranking official at the time believed that the use of mathematics in physics was unacceptable.

in which the values m , Δt and l took values measurable by real numbers. But in the range of hyperlight speeds $v > c$, these values m , Δt and l already took values measurable by open [55] Scipione Del Ferro, Niccolò Fontana Tartaglia, Gerolamo Cardano, Lodovico Ferrari and Raffaele Bombelli 400 years before the creation of SRT as imaginary numbers, the physical meaning of which, however, was incomprehensible to them and was not explained. And perhaps even earlier than them, imaginary numbers were discovered by Paolo Valmes

[56], who was burned alive at the stake for this by order of the inquisitor Tomás de Torquemada. Even Isaac Newton, in order to avoid trouble, preferred not to use imaginary numbers at that time⁶.

However, in order to explain the physical meaning of imaginary numbers, relativistic formulas must first be corrected so that they correspond to physically feasible processes. To do this, relativistic formulas (1)-(3) in the range $v > c$ must be such that the graphs of the functions

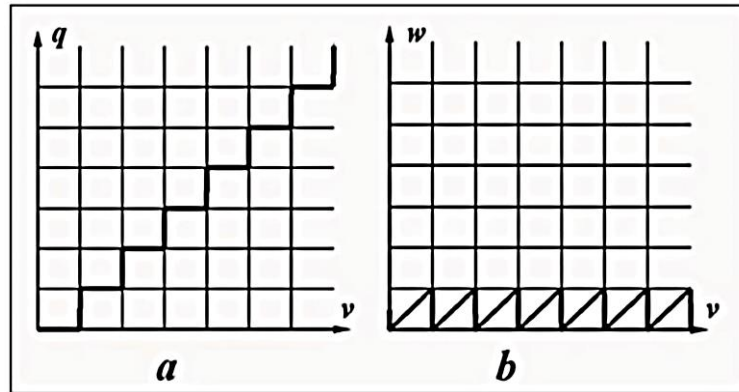


Fig. 3. Graphs of functions $q(v)$ and $w(v)$, illustrating the meaning of the 'floor' function in discrete mathematics

$m(v)$, $\Delta t(v)$, $l(v)$ (Fig. 1d,e,f) are similar to the graphs of the same functions $m(v)$, $\Delta t(v)$, $l(v)$ (Fig. 1a,b,c) in the range $v < c$. To do this, we need to introduce the function i^q into formulas (1)-(3)

$$m(q) = m_0 i_1^q / \sqrt{1 - (\frac{v}{c} - q)^2} \quad (4)$$

$$\Delta t(q) = \Delta t_0 i_1^q \sqrt{1 - (\frac{v}{c} - q)^2} \quad (5)$$

$$l(q) = l_0 i_1^q \sqrt{1 - (\frac{v}{c} - q)^2} \quad (6)$$

where $q(v) = [v/c]$ – the 'floor' function of discrete mathematics from the argument v/c (its graph is shown in Fig. 3a), which is the fourth spatial dimension;

$w = v - qc$ – local velocity in all universes (its graph is shown in Fig. 3b).

This function i^q in formulas (4)-(6), which defines the essence of each universe, for integer values ⁷ $q(v)$, equal to $0, 1, 2, 3, 4, 5$, takes the values $+1, +i, -1, -i, +1, +i, \dots$ etc. And the value $q(v) = 0$ in formulas (1)-(3) for the sublight speed range $v < c$ corresponds (since $i^0 = 1$) to our visible universe, which we will call the tardion⁸

universe for the sake of clarity. The value $q(v) = 1$ in the hyperlight speed range $2c > v > c$ corresponds (since $i^1 = i$) to some other invisible universe, since it is beyond the event horizon. For clarity, we will therefore call it the tachyonic⁹ universe. Then the value $q(v) = 2$ in the speed range $3c > v > 2c$ will correspond to (since $i^2 = -1$) an invisible tardion anti-universe, and the value $q(v) = 3$ in the speed range $4c > v > 3c$ will correspond to (since $i^3 = -i$) an invisible tachyonic anti-universe, the value $q(v) = 4$ in the speed range $5c > v > 4c$ will correspond (since $i^4 = +1$) to another (and therefore also invisible) tardionic universe, the value $q(v) = 5$ in the speed range $6c > v > 5c$ will correspond (since $i^5 = +i$) to another tachyon universe. And so on.

That is, according to formulas (4)-(6), there is not one visible universe, as claimed in the generally accepted version of SRT, but also a multitude of mutually invisible other universes and anti-universes, forming a Multiverse, which we will therefore call hidden. Such a hidden Multiverse, whose structure is winding, is shown in Fig. 4. And in this structure of the hidden Multiverse, the distribution of material content in each three-dimensional parallel universe and anti-

⁶ And his friend William Whiston, in the atmosphere of the omnipotence of the Inquisition, was stripped of his professorship and expelled from Oxford University for some of his careless remarks.

⁷ And for non-integer values of q , it is undefined.

⁸ Tardion universe is a term used by Isaak Asimov in his short story 'Take a Match'.

⁹ Tachyon universe is a term used by Isaak Asimov in his short story 'Take a Match'.

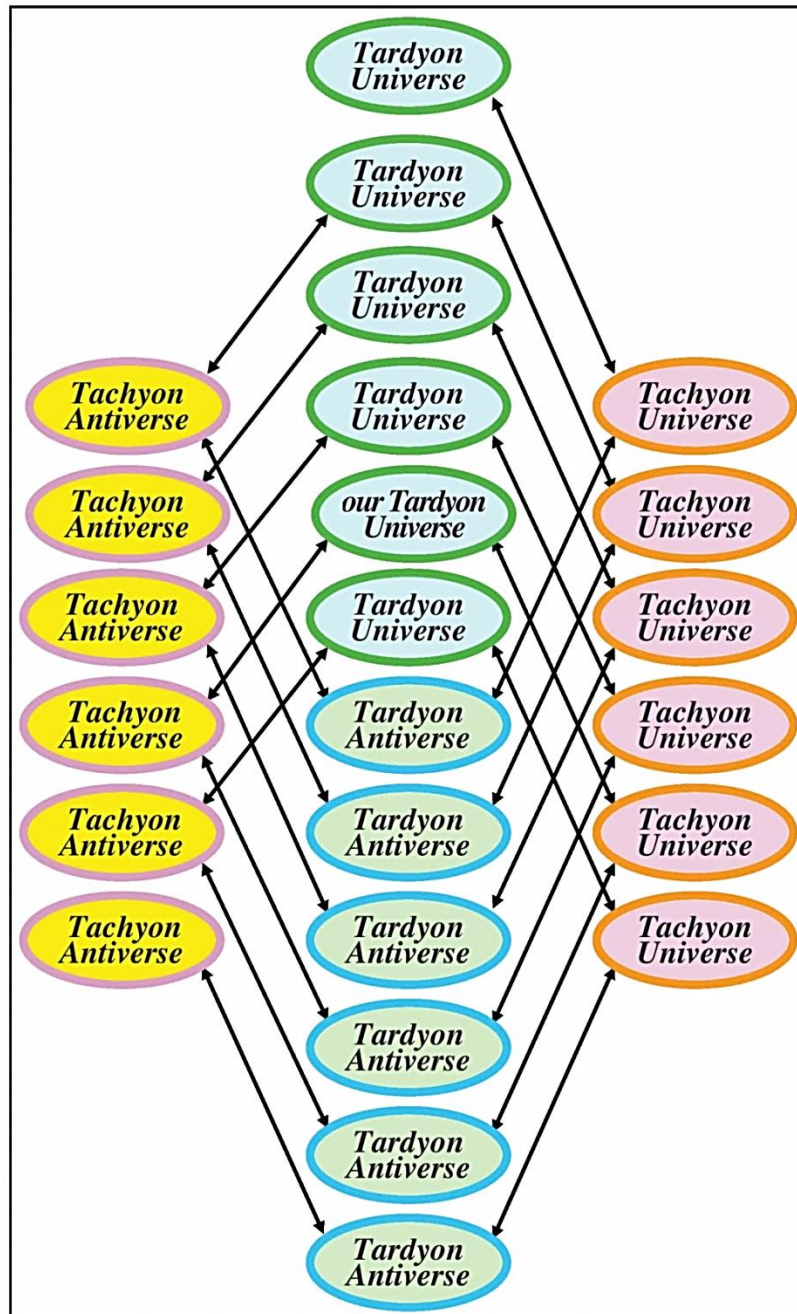


Fig. 4. Structure of the hidden Multiverse corresponding to the principle of physical reality of complex numbers

universe will be determined by its function $f_q(x, y, z)$, and the value iq will be the coordinate of these universes. That is, the hidden multiverse will be described by the formula $f_q(x, y, z) + iq$.

5. Analysis of data obtained by the WMAP and Planck spacecraft

But having proven the existence of mutually invisible parallel¹⁰ universes and anti-universes, necessary to find out how they are placed in the hidden Multiverse. Or, in other words, what is the structure of this hidden Multiverse? It is also necessary to understand what dark matter and dark energy are, so named because of their incomprehensibility, since no chemical elements have been found in them, and also because

they do not absorb, emit, reflect or refract any electromagnetic radiation, and are therefore invisible.

Moreover, dark matter and dark energy account for more than 95% of all mass-energy in the cosmos. More precisely, according to data obtained by the WMAP spacecraft [57], the mass-energy of our visible universe (actually a hidden Multiverse) consists of 4.6% baryonic matter, 22.4% dark matter, and 73.0% dark energy. And according to more recent data obtained by the Planck spacecraft [58], the entire universe (again, in fact, the entire hidden Multiverse) consists of 4.9% baryonic matter, 26.8% dark matter, and 68.3% dark energy.

Therefore, naturally, the reliability of other knowledge in modern physics, which is unable to explain the phenomena of dark matter and dark energy, is

¹⁰ Since they do not intersect

questionable. And since it has been proven beyond doubt that nature does not consist of a single universe, but a Multiverse, then, in addition to the still unsuccessful search in the microcosm for the nature of dark matter and dark energy phenomena at the Large Hadron Collider, it is necessary to begin searching for their explanation in the macrocosm of our hidden multiverse. After all, Albert Einstein himself wrote: *'It is meaningless to keep doing the same thing and expect different results'*. The ancient Chinese philosopher Confucius¹¹ said the same thing: *'The most difficult thing is to find a black cat in a dark room, especially if it is not there'*.

The search for a solution to this problem in the hidden Multiverse allows us to assume that [59]-[72]:

- dark matter and dark energy are most likely the rest of our hidden Multiverse, apart from our visible universe, tardion and tachyon universes and anti-universes, which are invisible to us because they exist in other dimensions;
- and since the universes and anti-universes of dark matter and dark energy are actually outside our visible universe, they manifest themselves in it only as phenomena (presumably in the form of gravitational shadows) generated by the existence of other invisible parallel universes and anti-universes of the hidden Multiverse¹²;
- dark matter is a phenomenon caused by the existence of invisible parallel universes and anti-universes in the hidden Multiverse neighbouring our visible universe.
- dark energy is a phenomenon generated by the existence of other universes besides our visible universe and its neighbouring invisible universes and anti-universes, other invisible parallel universes and anti-universes of the hidden Multiverse.

Therefore, dark matter and dark energy have no corpuscular content¹³. And they will never be detected at the Large Hadron Collider.

This explanation of the phenomena of dark matter and dark energy also provides information about the structure of the hidden Multiverse. Indeed, given that the mutually invisible universes and anti-universes of the hidden Multiverse are connected to each other by numerous portals through which they exchange their material contents, it can be argued that over billions of years of their existence, in accordance with the law of communicating vessels, their mass-energy has practically completely equalised. And then:

- according to experimental data obtained by the WMAP spacecraft, the entire hidden multiverse consists of $100\% / 4.6\% = 21.8$ parallel universes, and according to data obtained by the Planck spacecraft, it consists of $100\% / 4.9\% = 20.4$ parallel universes;

- dark matter, according to experimental data obtained by the WMAP spacecraft, consists of $22.4\% / 4.6\% = 4.9$ parallel universes, and according to data obtained by the Planck spacecraft, consists of $26.8\% / 4.9\% = 5.5$ parallel universes;

- according to experimental data obtained by the WMAP spacecraft, dark energy consists of $73.0\% / 4.6\% = 15.9$ parallel universes, and according to data obtained by the Planck spacecraft, it consists of $8.3\% / 4.9\% = 13.9$ parallel universes.

6. Corrected version of SRT, explanation of the phenomena of dark matter and dark energy

As can be seen, the experimental data obtained by the WMAP and Planck spacecraft did not confirm the above conclusions about the structure of the hidden multiverse, since our visible universe in this structure has not two neighbouring invisible parallel universes – one tachyon universe and one tachyon anti-universe – but five or six.

Therefore, it is obvious that there was some error in the previous reasoning. And it turns out that we were wrong in assuming that there is only one additional dimension q in the hidden Multiverse and, consequently, its correspondence to physically real complex numbers containing only one imaginary unit. In order for six¹⁴ other parallel universes – three tachyon universes and three tachyon anti-universes – to coexist with our visible universe in the actually existing hidden multiverse, it is necessary to have three additional dimensions q, r, s and the relativistic formulas must be corrected again as follows [73]-[81]

$$m(q, r, s) = \frac{m_0 i_1^q i_2^r i_3^s}{\sqrt{1 - [v/c - (q + r + s)]^2}} \quad (7)$$

$$\Delta t(q, r, s) = \Delta t_0 i_1^q i_2^r i_3^s \sqrt{1 - [v/c - (q + r + s)]^2} \quad (8)$$

$$l(q, r, s) = l_0 i_1^q i_2^r i_3^s \sqrt{1 - [v/c - (q + r + s)]^2} \quad (9)$$

where $q(v) = [v_q/c]$ – the ‘floor’ function of discrete mathematics from the argument v_q/c , which is one of the orthogonal coordinates q of the fourth spatial dimension v ;

$r(v) = [v_r/c]$ – the ‘floor’ function of discrete mathematics from the argument v_r/c , which is another orthogonal coordinate r of the fourth spatial dimension v ;

$s(v) = [v_s/c]$ – the ‘floor’ function of discrete mathematics from the argument v_s/c , which is one more orthogonal coordinate s of the fourth spatial dimension v ;

¹¹ Confucius was an ancient Chinese philosopher and statesman who lived more than two thousand years ago and remains the most famous Chinese person to this day. For a long time, Confucianism was as important in China as Buddhism. It forms the basis of modern state ideology.

¹² Similarly, for example, you may search unsuccessfully for a ringing telephone in the room you are in, when it is actually in the next room.

¹³ Like shadows on a sunny day.

¹⁴ Or less. Then some parallel universes of our hidden Multiverse may be absent and replaced by universes of neighbouring Multiverses.

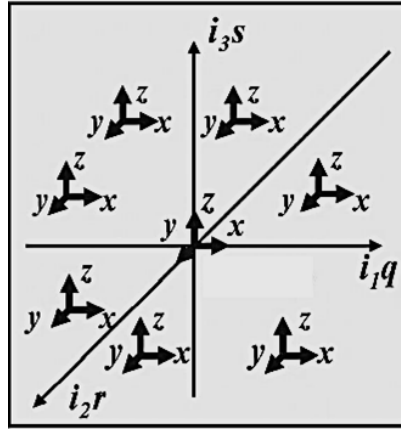


Fig. 5. Six-dimensional space of the hidden Multiverse, where q, r, s are the coordinates of invisible parallel universes, and x, y, z are the coordinates of the matter content in each parallel universe

v_q, v_r, v_s – projections of the velocity vector v onto the orthogonal coordinates q, r, s (see Fig. 5).

Consequently, the space of such a hidden multiverse will be six-dimensional (see Fig. 5). And its structure will correspond to the quaternions $\sigma + i_1\omega_1 + i_2\omega_2 + i_3\omega_3$, i.e. hyper complex numbers [82] containing precisely three imaginary units i_1, i_2, i_3 , which are related to each other by the following relations

$$i_1^2 = i_2^2 = i_3^2 = -1 \quad (10)$$

$$i_1 i_2 i_3 = i_2 i_3 i_1 = i_3 i_1 i_2 = -1 \quad (11)$$

$$i_1 i_3 i_2 = i_2 i_1 i_3 = i_3 i_2 i_1 = 1 \quad (12)$$

In such a quaternion structure of the hidden Multiverse [83], [84], unlike its structure considered earlier (in Fig. 4), the distribution of material content in each three-dimensional parallel universe will be determined by a function $f_{q,r,s}(x, y, z)$, and the coordinates of these universes will be determined by the values i_1q, i_2r и i_3s . That is, the hidden Multiverse will be described by the

formula $f_{q,r,s}(x, y, z) + i_1q + i_2r + i_3s$. This is exactly what Lisa Randall predicted: *'We could be living in a three-dimensional pocket of higher dimensional space.'*

And from formulas (7)-(9) it follows that such a hidden Multiverse still has a winding structure. In this case, it is possible to move from a tardion universe to a tardion antiuniverse and from a tardion antiuniverse to a tardion universe in different ways, but not in an arbitrary way, but only in such a way (see Fig. 6) that the value of i^q will successively take the values $+1, +i_1 \oplus +i_2 \oplus +i_3, -1, -i_1 \oplus -i_2 \oplus -i_3, +1, \dots$ and so on,

where $\oplus$ is the symbol of the logical operation of discrete mathematics 'exclusive OR'. In this case, different trajectories of movement from one universe (or antiuniverse) to another can differ only due to the replacement of some tachyon universes from i_1, i_2, i_3 with others and some tachyon antiuniverses from i_1, i_2, i_3 with others. Therefore, the tachyon universes i_1, i_2, i_3 in the hidden Multiverse are located parallel to each other. The tachyon antiuniverses i_1, i_2, i_3 are also located parallel to each other for the same reasons. And therefore, in the hidden Multiverse, when moving from any tardyon universe to a tardyon antiuniverse and then to another tardyon universe, parallel universes and antiuniverses must alternate in the following sequence – 'tardyon universe', 'one of the tachyon universes', 'tardyon antiuniverse', 'one of the tachyon antiuniverses', 'tardyon universe', 'one of the tachyon universes', etc.

One of the simplest explanations for such possible quaternion structures of the hidden multiverse is shown in Fig. 6. It differs from the structure shown in Fig. 4 in that it contains several parallel tachyon universes and anti-universes corresponding to the three imaginary units i_1, i_2, i_3 . Another difference is the presence in such a multiverse structure not only of bidirectional portals corresponding to formula (7) and marked with double-headed arrows, but also of unidirectional portals¹⁵, corresponding to formulas (8) and (9) and marked with single-headed arrows.

Moreover, naturally, the movement from our tardyon universe to the tardyon antiuniverse through some tachyon universe – for example, i_1 – does not necessarily have to proceed further through the tachyon antiuniverse i_1 . It can proceed further through the tachyon antiuniverses i_2 and

¹⁵ Why in such portals movement is possible only in one direction - from the entrance to the exit - is difficult for us, living in a space in which movement in nature is possible in any direction, to imagine. The processes that determine the possibility of such movement in nature are yet to be understood.

But for visitors who find themselves in such one-way portals, they are more dangerous than two-way portals, since it is impossible to return from them to your universe. Although in the metro with one-way movement on escalators we still encounter. But the metro is not nature.

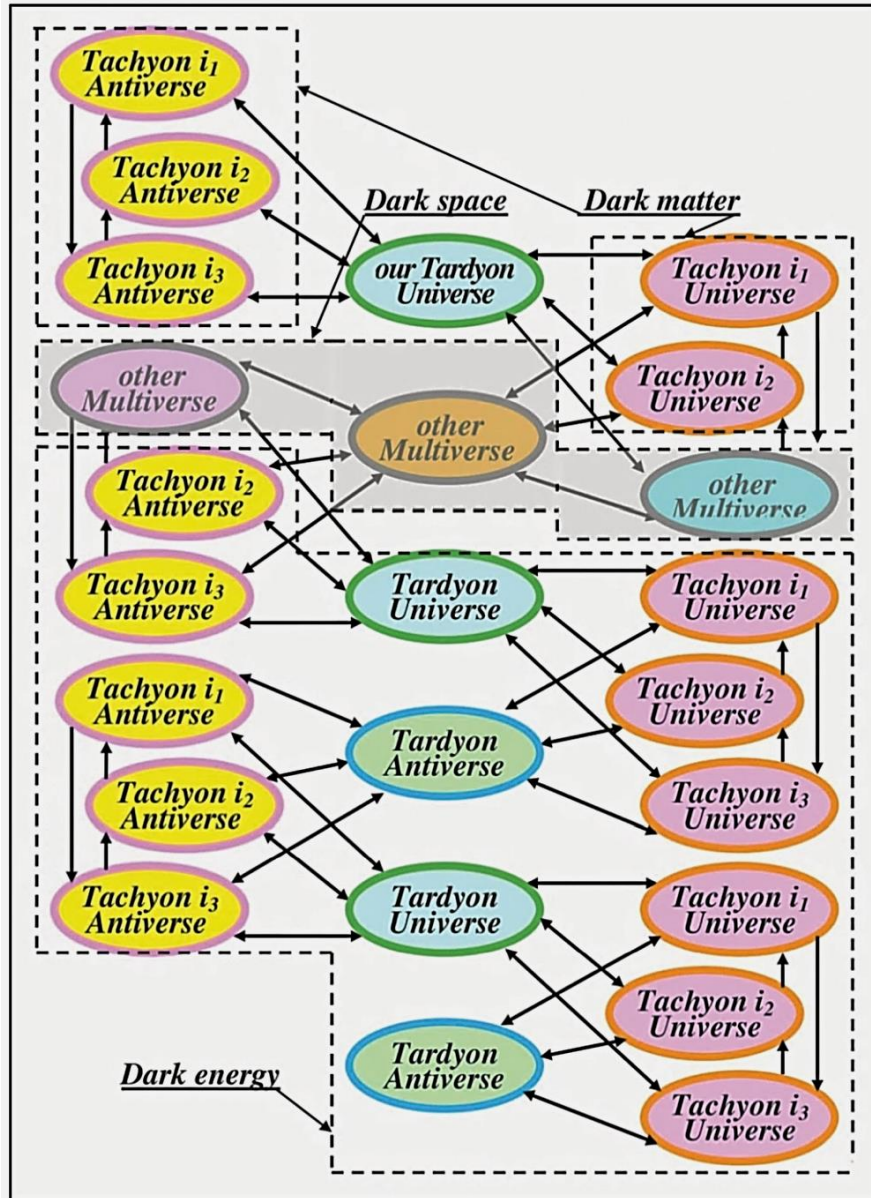


Fig. 6. Possible quaternion structure of the hidden Multiverse containing twenty-two parallel universes, including six invisible universes adjacent to our visible universe

i_3 . The same reservation applies to the situation if the movement from the tardyon universe to the tardyon antiuniverse begins through the tachyon universes i_2 and i_3 . All these transitions are shown

in Fig. 6. Moreover, since the data obtained by the WMAP and Planck spacecraft correspond to open helical structures of our hidden Multiverse, united through the corresponding portals with other Multiverses, then all of them together form the Hyperuniverse.

7. How to see invisible universes and antiuniverses

But to verify that these invisible universes really exist, we need an appropriate experiment that allows us to see them [85]-[98]. And to understand what this experiment might be like, we need to remember that in formulas (7)-(9), the parameters q , r , s are orthogonal coordinates of the fourth spatial dimension v , in which mutually invisible parallel universes somehow drift relative to each other. Therefore, they touch each other

and even slightly immerse into each other, forming corresponding transitions through which their material contents are exchanged. These transitions are usually called portals [99],[100]. And the entrances to them appear to be, at least, some of the anomalous zones, of which there are more than two hundred thousand on Earth. [101]-[104].

And since in other universes the constellations in the sky inevitably differ from the constellations in our earthly sky, when travelling through a portal from Earth to a neighbouring universe or anti-universe, the map of the starry sky in the portal will gradually transform into a map of the starry sky of that neighbouring universe or anti-universe. And if a telescope is placed in such a portal (or at least at its entrance in the anomalous zone), then by comparing the position of the stars in the sky in the portal and outside the portal, changes in the position of the stars can be detected. And if these differences turn out to be too small, then the telescope will have to be moved deeper into the portal. After all, Sir Arthur Stanley Eddington moved his telescope much further

for his famous experiment in the early 20th century – from England to the island of Principe in the Atlantic Ocean [105].

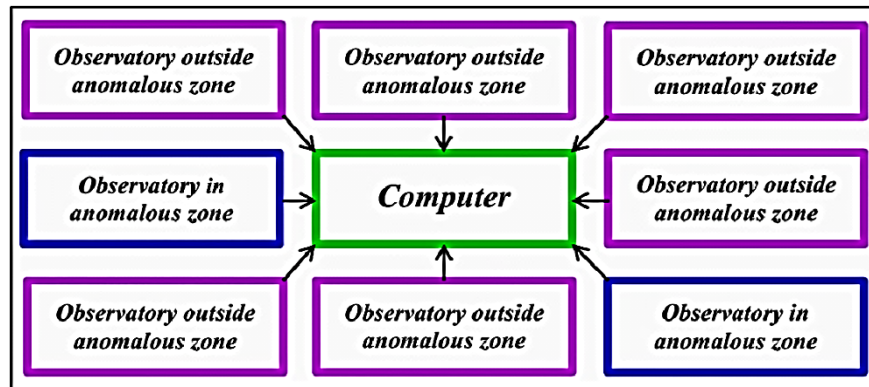


Fig. 7. Scheme of an astronomical experiment to detect invisible universes

These other constellations in the starry sky in the portals will serve as experimental proof of the existence of invisible universes and anti-universes outside the portals. The corresponding experiments (Fig. 7) are very inexpensive and easy to implement. Moreover, some observatories are already located in anomalous zones. For example, the Main Astronomical Observatory of the National Academy of Sciences of Ukraine is located 12 km from the centre of its capital, Kiev, in the Holosiivskyi Forest.

8. Antimatter and anti-time, external and internal time

Having convinced ourselves that the existence of the hidden Multiverse can be proven experimentally, let us continue to extract new knowledge from the revised version of SRT.

First, the structure of the hidden Multiverse already allows us to explain a problem that is currently inexplicable within the framework of physics textbooks: where is antimatter located [106]? It is clear that it cannot be found in our visible universe, since its annihilation with matter would cause our universe to cease to exist. But the fact that antimatter does exist has been proven experimentally. In 1995, a sensational result was obtained at CERN – scientists managed to obtain nine atoms of antihydrogen, which existed for about forty billionths of a second. And just one gram of such antihydrogen would cost 662.5 trillion (i.e. a thousand billion) dollars. Thus, the existence of antimatter has been experimentally proven.

This experiment can also be considered proof that, in accordance with formulas (7)-(9), antimatter can exist in nature, but only in the invisible tardion and tachyon anti-universes of the hidden Multiverse and Hyperuniverse. (see Fig. 6), since they are the antipodes of invisible tardion and tachyon universes.

Secondly, the existence in the hidden Multiverse of not only tardion and tachyon universes, but also anti-universes, makes it possible to travel not only in space, but also in time [107]-[127]. This refutes the claim of physicists who, although they recognise the hypothetical possibility of

time travel in certain exotic situations in special¹⁶ and general¹⁷ relativity and in quantum physics¹⁸, but deny the possibility of human time travel even in the distant future.

That is why the concept of the “arrow of time” [128], proposed at the beginning of the 20th century by Sir Arthur Stanley Eddington, even appeared in physics. And here is what Stephen William Hawking [129] wrote on this subject: *‘In everyday life, there is a huge difference between moving forward and backward in time. Imagine that a cup of water falls off the table and breaks into pieces. If you film this fall, it will be immediately clear when watching the film whether the film is being played forwards or backwards. If it is being played backwards, we will see the shards lying on the floor suddenly come together and, forming a whole cup, jump back onto the table. And you can say that the film was being played backwards, because in everyday life this does not happen. Otherwise, all the pottery factories would have to be closed down.’*

However, the existence of anti-time in the hidden Multiverse makes the use of the concept of ‘arrow of time’ unnecessary.

And finally, thirdly, it is easy to notice that in all the relativistic formulas (1)-(3); (4)-(6); (7)-(9) mentioned in the article, in addition to the functional dependencies of the quantities m , Δt , l on the argument v , there is another relativistic dependence – the quantity Δt on the argument l

$$\Delta t = \Delta t_0 l / l_0 \quad (10)$$

That is, it turns out that in nature there are not only the relativistic dependencies of physical quantities m , Δt , l on the velocity v that have already been identified and studied in the generally accepted version of STR, but also another relativistic dependency of external time Δt on the spatial coordinate l , perpendicular to the time zones, generated by the rotation of the Earth around its axis. And this external time differs from the internal (or, in other words, biological) time used in everyday life, which cannot flow backwards and people in it cannot return to their childhood. Unlike external time, which can flow both into the future and into the

¹⁶ For example, in the ‘twin paradox’

¹⁷ For example, in the region of ultra-high gravity near the event horizon of a black hole

¹⁸ For example, as a result of teleportation, instead of information, physical objects

past, since airplanes can cross time zones in both the western and eastern directions.

Moreover, unlike internal time, which always and everywhere flows at the same speed, this external time, measured by time zones, can flow at different speeds, depending on the speed of the aircraft and the size of the time zones.

Therefore:

- at the equator 1 time zone is equal to $\Delta l = 40075 \text{ km} \times \cos 0^\circ / 24 = 1700 \text{ km}$;
 - at the latitude of Santiago 1 time zone is equal to $\Delta l = 40075 \text{ km} \times \cos 33.45^\circ / 24 = 1426 \text{ km}$;
 - at the latitude of Buenos Aires 1 time zone is equal to $\Delta l = 40075 \text{ km} \times \cos 34.60^\circ / 24 = 1427 \text{ km}$;
 - at the latitude of Melbourne 1 time zone is equal to $\Delta l = 40075 \text{ km} \times \cos 37.82^\circ / 24 = 1358 \text{ km}$;
 - at the latitude of New York 1 time zone is equal to $\Delta l = 40075 \text{ km} \times \cos 40.72^\circ / 24 = 1269 \text{ km}$;
 - at the latitude of Reykjavik 1 time zone is equal to $\Delta l = 40075 \text{ km} \times \cos 64.15^\circ / 24 = 734 \text{ km}$;
 - at the latitude of Murmansk 1 time zone is equal to $\Delta l = 40075 \text{ km} \times \cos 69^\circ / 24 = 601 \text{ km}$;
 - at the latitude of Kirkenes 1 time zone is equal to $\Delta l = 40075 \text{ km} \times \cos 69.73^\circ / 24 = 599 \text{ km}$.
- Then the distance of 1 time zone an airplane with a speed of, for example, 800 km per hour, will fly:
- at the equator in $\Delta t = 1700 \text{ km} / 800 \text{ km per hour} = 2.125 \text{ hours}$ of internal (biological) human time;
 - at the latitude of Santiago in $\Delta t = 1426 / 800 \text{ km per hour} = 1.783 \text{ hours}$ of internal (biological) human time;
 - at the latitude of Buenos Aires in $\Delta t = 1427 / 800 \text{ km per hour} = 1.784 \text{ hours}$ of internal (biological) human time;
 - at the latitude of New York in $\Delta t = 1586 / 800 \text{ km per hour} = 1.983 \text{ hours}$ of internal (biological) human time;
 - at the latitude of Reykjavik for $\Delta t = 734 / 800 \text{ km per hour} = 0.918 \text{ hours}$ of internal (biological) human time;
 - at the latitude of Murmansk for $\Delta t = 601 / 800 \text{ km per hour} = 0.751 \text{ hours}$ of internal (biological) human time;
 - at the latitude of Kirkenes for $\Delta t = 599 / 800 \text{ km per hour} = 0.749 \text{ hours}$ of internal (biological) human time.

This happens because external time is the time outside the plane, determined by processes in the external environment, and internal time is the time measured by the watches of passengers and crew. And, it turns out, they are different. Therefore, after the plane lands, passengers have to change their watches to local time. And, as you can see, in order to travel to the past or the future, the plane's flight during its round-the-world trip must take place around the nearest pole close enough to it.

9. Revised version of SRT; how to verify the feasibility of travelling to the past and future

Moreover, even internal time itself can vary. Internal time may or may not depend on the distance a per-

son has travelled. For example, on a passenger aeroplane, it depends on this distance, but in a helicopter, it does not. But how much does it depend or not depend?

To answer this question, one would need to take a round-the-world trip by aeroplane. And after completing it and arriving in a city with the same name as the city from which the aeroplane departed, one would need to answer another obvious question: is it the same city or a different one? On a globe, it is, of course, the same city, but in reality, it is most likely a different city, since some changes have taken place in that city during the flight. And at the same time, these two (and if we also consider that the plane could have flown not only to the West, i.e. into the past, but also to the East, i.e. into the future, then even three) cities, which are already different in some ways, cannot exist in nature as they do on the globe. But if two such flights (one to the past, the other to the future) took off from the same aerodrome at the same time and arrived at the same time, could these two different aerodromes coexist?

The answer to this question is simple. At the point of arrival, they may also meet their double. And if they exist, then twin cities also exist – both in the past and in the future. Then, naturally, the Earth is somehow more complex than a globe.

Therefore, formula (10) in SRT will have to be corrected. Perhaps as follows

$$\Delta t = \Delta t_0 i^{1/10} l / l_0 \quad (11)$$

where $\Delta t_0 = 24$ – the length of a day in hours (and the number of time zones);

Δt – duration of travel in time in hours;

l_0 – length of travel in space with the crossing of 24 time zones;

l – length of travel in space with the crossing of the required number of time zones.

10. Conclusion

Our visible world is still largely unknown, as confirmed by numerous scientific discoveries made over the past decades. But this visible world is immersed in a vast and almost completely unknown invisible world, which some scientists, however, do not even want to acknowledge or study. For example, relativistic physicists, for career reasons, still refuse to acknowledge the physical reality of imaginary numbers, which experimentally prove that the generally accepted version of the special theory of relativity is incorrect. And they are not even bothered by the fact that if the generally accepted version of SRT were correct, then neither electrical engineering, nor radio engineering, nor computer engineering, nor many other things would exist. Even church bells would not be able to sound, and swings would not be able to swing in playgrounds.

But nevertheless, this incorrect version of SRT is currently studied in all physics textbooks. These textbooks are used in the educational process all over the world, even in the most prestigious universities, and have been hindering the development of science for over 100 years. Therefore, it is not surprising that the phenomena of dark matter and dark energy, discovered in the 20th century, which are experimental refutations of the incorrect version of SRT, have still not been explained in textbooks. And they will never be explained by experiments at the Large Hadron Collider, since no

such explanation exists in the microcosm. In reality, as follows from the analysis of experimental data obtained by the WMAP and Planck spacecraft, dark matter and dark energy are not objects of the microcosm that everyone is looking for at the Large Hadron Collider, but objects of the macrocosm, which are mutually invisible universes and anti-universes of the hidden Multiverse.

Analysis of these experimental data not only explained the phenomena of dark matter and dark energy, but also revealed the quaternion structure of the hidden Multiverse, whose anti-universes contain anti-time. Thus, in the manner described above, the concept of the "arrow of time" is corrected, proving not only the possibility but also the actual use of time travel by humans. This applies not only to space but also to Earth, using its existing time zones. This refutes the categorical assertion of physicists that time travel is impossible for humans to use in their practical activities

References:

1. Einstein A. (1920). *Relativity: The Special and General Theory*. H. Holt and Company. NY.
2. Bohm D. (2006). *The Special Theory of Relativity*. Routledge, Abingdon on Thames.
3. Penrose R. (2010). *The Nature of Space and Time*. Princeton University Press. Princeton.
4. Larmor J.J. (1897). A Dynamical Theory of the Electric and Luminiferous Medium. Part III. Relations with Material Media. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. 190, 205-300.
5. Lorentz H.A. (1899). Simplified Theory of Electrical and Optical Phenomena in Moving Systems. *Proceedings of the Netherlands Academy of Arts and Science*. Amsterdam. 1, 427-442.
6. Poincaré H. (1905). On the Dynamics of the Electron. *Comptes Rendus*. 140. 1504-1508.
7. Einstein A. (1905). Zur Elektrodynamik bewegter Körper. *Annals of Physic*. 17. 891-921.
8. Adam T., Agafonova N., Aleksandrov A. et al. (2012). Measurement of the neutrino velocity with the OPERA detector in the CNGS beam. arxiv:1109.4897v4 [hep-ex].
9. Antonov A. A. (2008). Physical Reality of Resonance on Complex Frequencies. *European Journal of Scientific Research*. 21(4). 627-641. <http://www.eurojournals.com/ejsr.htm>
10. Antonov A. A. (2009). Resonance on Real and Complex Frequencies. *European Journal of Scientific Research*. 28(2). 193-204. <http://www.eurojournals.com/ejsr.htm>
11. Antonov A. A. (2010). New Interpretation of Resonance. *International Journal of Pure and Applied Sciences and Technology*. 1(2). 1-12. http://doi.org/10.17686/sced_rusnauka_2010-888
12. Antonov A. A. (2010). Oscillation processes as a tool of physics cognition. *American Journal of Scientific and Industrial Research*. 1(2). 342-349. doi:10.5251/ajsir.2010.1.2.342.349
13. Antonov A. A. (2010). Solution of algebraic quadratic equations taking into account transitional processes in oscillation systems. *General Mathematics Notes*. 1(9). 11-16. http://doi.org/10.17686/sced_rusnauka_2010-887
14. Antonov A. A. (2013). Physical Reality of Complex Numbers. *International Journal of Management, IT and Engineering*. 3(4). 219-230. http://doi.org/10.17686/sced_rusnauka_2013-898
15. Antonov A. A. (2014). Correction of the special theory of relativity: physical reality and nature of imaginary and complex numbers. *American Journal of Scientific and Industrial Research*. 5(2). 40-52. doi:10.5251/ajsir.2014.5.2.40.52
16. Antonov A. A. (2015). Physical reality of complex numbers is proved by research of resonance. *General Mathematics Notes*. 31(2). 34-53. http://www.emis.de/journals/GMN/yahoo_site_admin/asets/docs/4_GMN9212-V31N2.129701.pdf
17. Antonov A.A. (2015). Principle of physical reality of imaginary and complex numbers in modern cosmology: the nature of dark matter and dark energy. *Journal of the Russian physico-chemical society*. 87(1). 328-355. (In Russian) http://doi.org/10.17686/sced_rusnauka_2015-1119
18. Antonov A. A. (2016). Physical Reality and Nature of Imaginary, Complex and Hypercomplex Numbers. *General Mathematics Notes*. 35(2). 40-63. http://www.geman.in/yahoo_site_admin/asets/docs/4_GMN-10932-V35N2.31895146.pdf
19. Antonov A. A. (2017). The physical reality and essence of imaginary numbers. *Norwegian Journal of development of the International Science*. 6. 50-63. <http://www.njd-iscience.com>
20. Antonov A. A. (2018). Physical Reality and Essence of Imaginary Numbers in Astrophysics: Dark Matter, Dark Energy, Dark Space. *Natural Science*. 10(1). 11-30. doi:10.4236/ns.2018.101002
21. Antonov A. A. (2021). Version of the special theory of relativity that is studied in all physics textbooks is incorrect. *Österreichisches Multiscience Journal (Innsbruck, Austria)*. 43(1). 17-22. <http://osterr-science.com>
22. Antonov A. A. (2021). The fallacy of the SRT version studied in physics textbooks proved experimentally. *Österreichisches Multiscience Journal (Innsbruck, Austria)*. 45(1). 17-26.
23. Antonov A. A. (2021). Generally accepted version of the special theory of relativity contained in physics textbooks is incorrect. The scientific heritage. (Budapest, Hungary). 73(2). 39-43. DOI: 19.24412/9215-0365-2021-73-2-39-43
24. Antonov A. A. (2021). Special theory of relativity, which is studied in physics text-books, is incorrect. *German International Journal of Modern Science*. 16, 49-53. DOI: 10.24412/2701-8369-2021-16-49-53
25. Antonov A. A. (2021). Special theory of relativity, which is studied in all physics textbooks, is incorrect. *Danish Scientific Journal*. 51(1). 31-35. <http://www.danish-journal.com>
26. Antonov A. A. (2021). Special theory of relativity taught in all physics text-books is incorrect. *Annali d'Italia*. 22(1). 39-44. <https://www.anditalia.com/>

27. Antonov A. A. (2021). Special theory of relativity presented in physics text-books is wrong. Norwegian Journal of development of the International Science 68(1). 3-7.
DOI: 10.24412/3453-9875-2021-68-3-7.
28. Antonov A. A. (2021). In all physics textbooks an erroneous version of special theory of relativity is given. International independent scientific journal. 31.34-39. <http://www.iis-journal.com>
29. Antonov A. A. (2021). Special theory of relativity taught in physics textbooks is wrong. Journal of science. Lyon. 23. 47-52. <https://www.joslyon.com/>
30. Antonov A. A. (2021). All physics textbooks study incorrect special theory of relativity. Sciences of Europe. (Praha, Czech Republic) 79(1). 30-35.
DOI: 10.24412/3162-2364-2021-79-30-35
31. Antonov A. A. (2022). The version of STR presented in physics textbooks is incorrect, since it follows from it that radio engineering should not exist. European Journal of Applied Sciences. Services for Science and Education. UK. 10(1). 440-445.
DOI: <https://doi.org/10.14738/aivp.101.2022>
32. Antonov A. A. (2022). The existence of radio engineering refutes the physics text-books version of STR. The scientific heritage. (Budapest, Hungary). 83(1). 19-22.
DOI: 10.24412/9215-0365-2022-83-1-19-22
33. Antonov A.A. (2022). The fundamental Ohm's law in radio engineering as interpreted by Steinmetz, which proves the physical reality on imaginary capacitive and inductive reactances, refuted the version of the STR presented in physics textbooks even before its creation. German International Journal of Modern Science. 26. 50-53. DOI: 10.24412/2701- 8369-2022-26-50-63
34. Antonov A.A. (2022). The version of STR stated in physics textbooks is refuted by the existence of radio engineering. Danish Scientific Journal. 56. 56-59. <http://www.danish-journal.com>
35. Antonov A.A. (2022). The version of STR presented in physics textbooks is in correct because it denies the possibility of the existence of Ohm's law as interpreted by Steinmetz and, consequently, the existence of radio engineering. Annali d'Italia. 28(1), 43-47.
<https://www.anditalia.com/>
36. Antonov A.A. (2022). The version of STR stated in physics textbooks is refuted by the existence of radio engineering. Norwegian Journal of development of the International Science. 78(1). 63-67. DOI: 10.24412/3453-9875-2022-78-63-66.
37. Antonov A.A. (2022). If the physics textbook version of STR were true, then Ohm's law should not exist in nature, and therefore all radio engineering would not exist. International independent scientific journal. 36. 16-19. <http://www.iis-journal.com>
38. Antonov A.A. (2022). If the version of STR in physics textbooks were true, then there would be no radar, no television, no radio navigation, no telecommunication and many other things. Journal of science. Lyon. 28. 76-79. <https://www.joslyon.com/>
39. Antonov A.A. (2022). The version of STR set out in physics textbooks is in-correct because it states that Ohm's law as interpreted by Steinmetz does not really exist, and therefore radio engineering does not exist either. Sciences of Europe (Praha, Czech Republic). 87(1). 54-57. DOI: 10.24412/3162-2364-2022-1-54-57
40. Antonov A.A. (2022). Why the physics textbooks teach an incorrect version of the special theory of relativity which denies the existence of radio- and electrical engineering. III international scientific conference "Challenges and problems of modern science". London. Great Britain. 78-86. <https://doi.org/10.5281/zenodo.7486814>
41. Antonov A. A. (2023). Why is the incorrect version of the special theory of relativity being studied in physics text-books, refuted the existence of radio- and electrical engineering even before its creation? The scientific heritage. (Budapest, Hungary). 105. 83-89.
DOI: 10.5281/zenodo.7560145
42. Antonov A.A. (2023). Why is an incorrect version of the special theory of relativity that denies the possibility of the existence radio and electrical engineering being studied in physics textbooks? German International Journal of Modern Science. 48. 23-29.
DOI: <https://doi.org/10.5281/zenodo.7541137>
43. Antonov A.A. (2023). Who needs the incorrect version of special relativity taught in physics textbooks despite all its experimental refutations? Annali d'Italia. 39, 64-70.
DOI: 10.5281/zenodo.7568916
44. Antonov A.A. (2023). Why is incorrect version of the special theory of relativity that denies the possibility of the existence of radio and electrical engineering being studied in textbooks of physics? Norwegian Journal of development of the International Science. 100. 27-33. <https://doi.org/10.5281/zenodo.7528512>
45. Antonov A.A. (2023). Why is incorrect version of the special theory of relativity, refuted by the existence of radio and electrical engineering, is still studies in all university physics textbooks? Danish Scientific Journal. 69. 66-72. <https://doi.org/10.5281/zenodo.7692053>
46. Antonov A.A. (2023). Why is incorrect version of the special relativity still being studied in physics textbooks, which denies Ohm's law for alternating current used worldwide by millions of radio- and electrical engineers? International independent scientific journal. 46. 38-44. <https://doi.org/10.5281/zenodo.7525751>.
47. Antonov A.A. (2023). Why is the generally accepted version of STR, which denies the possibility of the existence of radio engineering and electrical engineering, tsunamis and bell ringing, the physical phenomenon of resonance and Ohm's physical law for alternating current, music created by the piano and even swing swings on the playground, nevertheless is still considered correct and studied in physics textbooks? Sciences of Europe (Praha, Czech Republic). 112. 44-50. DOI: 10.5281/zenodo.7708515
48. Antonov A.A. (2023). Why is the incorrect version of the special theory of relativity still being studied in physics textbooks, despite all its experimental refutations. European Journal of Applied Sciences. Services for Science and Education. UK. 11(2). 61-71.
DOI: <https://doi.org/10.14738/aivp.112.14128>

49. Antonov A. A. (2023). Why the incorrect version of the special theory of relativity, which denies the possibility of the existence of radio engineering and electrical engineering, has not yet been refuted. *Journal of science. Lyon.* 40. 19-25.
<https://doi.org/10.5281/zenodo.7704392>
50. Steinmetz C. P. (2010). *Theory and Calculation of Electric Circuit.* Nabu Press.
51. Harsha P. (2012). On the Dual Real Value Nature of Complex Numbers. *International Journal of Scientific & Engineering Research.* 3(2). 1-4.
<https://www.ijser.org/researchpaper/On-the-Dual-Real-Value-Nature-of-Complex-Numbers.pdf>
52. Shpenkov G. P. (2014). Physical sense of imaginary unit i. *Encyclopaedia of Russian thought: Papers to the Russian Physical Society.* 20(2). 70-81. (In Russian)
<http://www.rusphysics.ru/files/Shpenkov.Fisc.smysl.pdf>
53. Akhkozov, Y. L. (2014). Florensky's physical plane as the basis of the substratum of the universe. *Encyclopaedia of Russian Thought: Reports to the Russian Physical Society.* 23(2). 46-82. (In Russian) .
<http://www.rusphysics.ru/files/Ahkosov.pdf>
54. Lyahov V. V., Neshchadim V. M. (2018). *Models of plasma kinetics and problem with their interpretation in the current paradigm.* Nova science publishers, NY.
55. Weinstein E. W. (2005). *The CRC Concise Encyclopedia of Mathematics.* 3-rd ed. CRS Press. Boca Raton. FL.
56. Beckmann P. (1976). *A history of π .* 3rd edition. St. Martin Press. NY.
57. Hinshaw G., Larson D., Komatsu E., et al. (2013) Nine Year Wilkinson Anisotropy Probe (WMAP) Observations: Cosmological Parameter Results. arXiv:1213.5226 [astro-ph/CO].
58. Adam R., Ade P. A. R., Aghanim N., et al. (2015). Planck 2015 Results. 1. Overview of Products and Scientific Results. arXiv:1502.01582v2 [astro-ph.CO].
59. Antonov A. A. (2015). Hidden Multiverse. *International Journal of Advanced Research in Physical Science.* 2(1). 25-32.
http://doi.org/10.17686/sced_rusnauka_2015-903.
60. Antonov A. A. (2015). The astrophysical phenomenon of dark matter and dark energy proves the existence of the hidden Multiverse. *American Journal of Modern Physics.* 4(4). 180-188. DOI: 10.11648/j.jamp.20150404.14
61. Antonov A. A. (2015). Hidden Multiverse: explanation of dark matter and dark energy phenomena. *International Journal of Physics.* 3(2). 84-87. doi:10.12691/ijp-3-2-6
62. Antonov A. A. (2015). Principles and structure of the real Multiverse: explanation of dark matter and dark energy phenomena. *American Journal of Modern Physics.* 4(1). 1-9.
doi: 10.11648/j.ajmp.20150401.11
63. Antonov A. A. (2015). The astrophysical phenomenon of dark matter and dark energy proves the existence of the hidden Multiverse. *American Journal of Modern Physics.* 4(4). 180-188. doi: 10.11648/j.jamp.20150404.14
64. Antonov A. A. (2015). Why dark matter and dark energy are invisible? *Optics.* 4(6), 43-47. doi: 10.11648/j.optics.20150406.12
65. Antonov A. A. (2015). Hidden Multiverse: explanation of dark matter and dark energy phenomena. *International Journal of Physics.* 3(2). 84-87. doi:10.12691/ijp-3-2-6
66. Antonov A. A. (2015). Principles and structure of the real Multiverse: explanation of dark matter and dark energy phenomena. *American Journal of Modern Physics.* 4(1). 1-9.
doi:10.11648/j.ajmp.20150401.11
67. Antonov A. A. (2015). Explanation of dark matter and dark energy phenomena. *Journal of Science Frontier Research: A Physics and Space Science.* 15(1). 33-38.
http://doi.org/10.17686/sced_rusnauka_2015-902
68. Antonov A. A. (2015). Review of publications by A. A. Antonov on the problem of explaining the phenomenon of dark matter and dark energy. *Journal of the Russian physico-chemical society.* 87(3). 63-76. (In Russian)
69. Antonov A. A. (2016). Hypothesis of the Hidden Multiverse: Explains Dark Matter and Dark Energy. *Journal of Modern Physics.* 7(10), 1228- 1246. doi: 10.4236/jmp.2016.710111
70. Antonov A. A. (2016). Explaining the Phenomenon of Dark Matter and Dark Energy by Existence of the Hidden Multiverse. *Frontiers of Astronomy, Astrophysics and Cosmology.* 2(1). 1-9. doi: 10.12691/faac-2-1-1
71. Antonov A. A. (2017). Nature of dark matter and dark energy. *Journal of Modern Physics.* 8(4). 567-582. doi: 10.4236/jmp.2017.84038
72. Antonov A. A. (2017). Hypothesis of the hidden Multiverse explains the phenomenon of dark matter and dark energy. *Applied Physics Research.* 9(2). 30-41.
doi: <https://doi.org/10.5539/apr.v9n2p30>
73. Antonov A. A. (2023). The Corrected Version of the Special Theory of Relativity. *European Journal of Applied Sciences. Services for Science and Education.* UK. 11(5). 68-83.
DOI:10.14738/aijp.115.15474
74. Antonov A. A. (2023). Corrected special theory of relativity. *Journal of science. Lyon.* 47. 14-23. <https://doi.org/10.5281/zenodo.10068983>
75. Antonov A. A. (2023). Corrected special theory of relativity. *Annali d'Italia.* 49, 25-35. DOI: 10.5281/zenodo.10214679
76. Antonov A. A. (2023). Corrected special theory of relativity. *Journal of science. Lyon.* 48. 27-36. <https://doi.org/10.5281/zenodo.10277156>
77. Antonov A. A. (2023). The Corrected Version of the Special Theory of Relativity. *The scientific heritage. (Budapest, Hungary).* 123. 72-81,
78. Antonov A. A. (2023). The Corrected Version of the Special Theory of Relativity. *Norwegian Journal of development of the International Science.* 118. 40-49.
<https://doi.org/10.5281/zenodo.10009500>

79. Antonov A. A. (2023). Alternative Version of the Special Theory of Relativity. Sciences of Europe. (Praha, Czech Republic). 128. 62-71.
80. Antonov A. A. (2023). Special Theory of Relativity. German International Journal of Modern Science. 67. 64-73. DOI: 10.5281/zenodo.10966458
81. Antonov A. A. (2023). Corrected Version of the Special Theory of Relativity. Danish Scientific Journal. 77. 88-97. <https://doi.org/10.5281/zenodo.10054677>
82. Kantor I. L., Solodovnikov A. S. (1989). Hypercomplex Numbers: An Elementary Introduction to Algebras. Springer-Verlag
83. Antonov A. A. (2015). Quaternion structure of the hidden Multiverse: explanation of dark matter and dark energy. Global Journal of Science. Frontier Research A: Physics and Space Science. 15(8). 8-15. https://globaljournals.org/GJSFR_Volume15/2-Quaternion-Structure-of-the-Hidden.Pdf
84. Antonov A. A. (2016). Verifiable Multiverse. Global Journal of Science Frontier Research: A Physics and Space Science. 16(4) 4-12. doi: 10.17406/GJSFR
85. Antonov A. A. (2020). How to See Invisible Universes. Journal of Modern Physics. 11(05), 593-607. DOI: 10.4236/jmp.2020.115039
86. Antonov A. A. (2020). Can invisible universes be seen? International independent scientific journal. 21(2). 51-60. <http://www.iis-journal.com>
87. Antonov A. A. (2020). How to discover invisible universes. Norwegian Journal of development of the International Science. 42(1). 36-48. <http://www.njd-iscience.com>
88. Antonov A. A. (2020). Universes Being Invisible on Earth outside the Portals Are Visible in Portals. Natural Science. 12(8). 569-587. <https://doi.org/10.4236/ns.2020.128044>
89. Antonov A. A. 2024. Proof of the existence of other mutually invisible universes neighboring to our visible universe by astronomical observations in the portals of constellations invisible outside the portals. Sciences of Europe (Praha, Czech Republic). 153. 93-106. DOI: 10.5281/zenodo.14227583
90. Antonov A. A. (2020). Invisible universes can be seen in anomalous zones. Danish Scientific Journal. 43(1). 9-24. <http://www.danish-journal.com>
91. Antonov A. A. (2021). Invisible universes can be seen in anomalous zones. International independent scientific journal. 23(1). 28-44.
92. Antonov A. A. (2024). Proof of the existence of other mutually invisible universes neighboring to our visible universe by astronomical observations in the portals of constellations invisible outside the portals. Annali d'Italia. 61. 43-57. DOI: 10.5281/zenodo.14230824
93. Antonov A. A. (2024). Proof of the existence of other mutually invisible universes neighboring to our visible universe. Danish Scientific Journal 90. 111-125. <https://doi.org/10.5281/zenodo.14236925>
94. Antonov A. A. (2024). Existence of other mutually invisible universes adjacent to our visible universe can be experimentally proven by astronomical observations in the portals of constellations invisible outside the portals. German International Journal of Modern Science. 92. 67-80.
95. Antonov A. A. (2024). Discovery of constellations in portals that are invisible outside the portals proves the existence of mutually invisible universes adjacent to our visible universe. Sciences of Europe (Praha, Czech Republic). 94. 34-48. DOI: 10.5281/zenodo.14167218
96. Antonov A. A. (2024). Discovery of other constellations in portals that are invisible outside the portals is experimental proof of the existence of mutually invisible universes adjacent to our visible universe. Polish journal of Science. 80. 24-38.
97. Antonov A. A. (2024). It is possible to prove the existence of other mutually invisible universes adjacent to our visible universe by astronomical observations in the portals of constellations that are invisible outside the portals. Slovak international scientific journal (Bratislava, Slovakia). 89. 51-65. DOI: 10.5281/zenodo.14167109
98. Antonov A. A. (2024). Experimental evidence for the existence of other mutually invisible universes neighboring our visible universe. European Journal of Applied Sciences. Services for Science and Education. UK. 12(5). 385-408. DOI: 10.14738/aivp.125.17785.
99. Antonov A. A. (2012). Earth, portals, parallel universes. American Journal of Scientific and Industrial Research. 3(6). 464-473. doi: 10.5251/ajsir.2012.3.6.464.473
100. Antonov A. A. (13 January 2016). How Portals of the Invisible Multiverse Operate. Science PG Frontiers <http://www.sciencepublishing-group.com/news/sciencepgfrontiersinfo?articleid=7>
101. Chernobrov, V. (2000). Encyclopedia of mysterious places of the Earth. Veche Publishing House. Moscow. (In Russian)
102. Chernobrov, V. (2004). Encyclopedia of mysterious places of Russia. Veche Publishing House. Moscow. (In Russian)
103. Chernobrov, V. (2007). Encyclopedia of mysterious places of Earth and space. Veche Publishing House. Moscow. (In Russian)
104. Chernobrov, V. (2009). Encyclopedia of mysterious places of Moscow and Moscow region. Helios ARV. Moscow. (In Russian)
105. Antonov A.A. (2016). Dark matter, dark energy and antimatter are located in the hidden Multiverse. PONTE. 72(8). 288-300.
106. Antonov A. A. 2021. Antimatter, Anti-Space, Anti-Time. Journal of Modern Physics, 12(05), 646-660. DOI: 10.4236/jmp.2021.125042.
107. Antonov A. A. 2025. Time travels for people on Earth are already possible. European Journal of Applied Sciences, Services for Science and Education. UK. 13(1). 163-180. DOI: 10.14738/aivp.131.18239.
108. Antonov A. A. 2025. Time travels for people on Earth is already realistically physically feasible. The scientific heritage. 155. 54-65. DOI: 10.5281/zenodo.14914569

109. Antonov A. A. 2025. How do you build a time machine? German International Journal of Modern Science. 98. 46- 57. DOI: 10.5281/zenodo.14910894
110. Antonov A. A. 2024. Time travels, both to the future and to the past, is physically possible. Danish Scientific Journal. 93. 117-128. <https://doi.org/10.5281/zenodo.14959204>
111. Antonov A. A. 2025. Creating a time machine is already possible Annali d'Italia. 64. 54-65. DOI: 10.5281/zenodo.14937513
112. Antonov A. A. 2025. Time travels for people on Earth are already realistically physically available. Norwegian Journal of development of the International Science. 150. 96-107. <https://doi.org/10.5281/zenodo.14870598>
113. Antonov A. A. 2025. Time travels for people on Earth is physically possible. Polish journal of Science. 83. 44-55. DOI: 10.5281/zenodo.14895232
114. Antonov A. A. 2024. Time travels are already possible for people on Earth. Slovak international scientific journal. 92. 83-93. DOI: 10.5281/zenodo.14870073
115. Antonov A. A. 2025. The physical possibility for people on Earth to time travels. Znanstvena misel journal. 99. 65-75. DOI: 10.5281/zenodo.14919742
116. Antonov A. A. 2025. Creating a time machine. Journal of Science. Lyon. 62. 29-40. <https://doi.org/10.5281/zenodo.14824392>
117. Antonov A. A. 2025. Physical feasibility of time travels for people on Earth. Sciences of Europe (Praha, Czech Republic). 159. 47-57. DOI: 10.5281/zenodo.14956952
118. Antonov A. A. 2025. The physical ability to bring a person who has died, for example as a result of an accident or a crime, back to life. Polish journal of Science. 89. 36-39.
119. Antonov A. A. 2025. The use of the laws of physics allows a person who has died, for example, as a result of an accident or crime, to be brought back to life. European Journal of Applied Sciences. Services for Science and Education. UK. 13(04). 174-179. DOI:10.14738/aivp.1304.19179.
120. Antonov A. A. 2025. It is physically possible to bring back to life a person who has died, for example, as a result of an accident or crime, using time travels. German International Journal of Modern Science. 109. 24-27. DOI: 10.5281/zenodo.16752567
121. Antonov A. A. 2025. The laws of physics allow a person who has died, for example, as a result of an accident or crime, to be brought back to life. Danish Scientific Journal. 98. 67-70. <https://doi.org/10.5281/zenodo.16615081>
122. Antonov A. A. 2025. It is physically possible to bring back to life a person who has died as a result of an accident or crime by using time travels. Annali d'Italia journal. 69. 46-49. DOI: 10.5281/zenodo.16419980
123. Antonov A. A. 22-23.07.2025. Possibility in accordance with the laws of physics, of bringing back to life people who have died as a result of accident and other causes by time travels using time zones on Earth. XVI international scientific conference "Science in modern society". Beijing. China. 36-40. DOI <https://doi.org/10.5281/zenodo.16562393>
124. Antonov A. A. 2025. How the laws of physics can be used to bring back to life a person who has died as a result of an accident or crime. Norwegian Journal of development of the International Science. 160. 69-72. <https://doi.org/10.5281/zenodo.15879906>
125. Antonov A. A. 2025. A person who has died in an accident or crime, for example, can be brought back to life through the use of time travels. International independent scientific journal. 72. 17-20. <https://doi.org/10.5281/zenodo.16778574>
126. Antonov A. A. 2025. The laws of physics allow a dead person to be brought back to life. Journal of Science. Lyon. 68. 15- 18. <https://doi.org/10.5281/zenodo.16758455>
127. Antonov A. A. 12-13.08.2025. The laws of physics allow by time travelling with using time zones on Earth to bring back to life people who died as a result of accidents, in war and for other reasons. XVII International scientific conference "Theoretical and practical perspectives of modern science". Stockholm. Sweden. 24-28. DOI <https://doi.org/10.5281/zenodo.16892861>
128. Eddington A. S. (1928). Nature of the Physical World. Cambridge University Press. London
129. Hawking S.W. (1988). Brief History of Time: From the Big Bang to Black Holes. Bantam Dell Publishing Group. UK.

PSYCHOLOGICAL SCIENCES

INFORMATION EQUATION OF EMOTIONAL STATE

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Abstract

This paper proposes a mathematical model of human emotional states within the framework of information theory. Building on P. V. Simonov's model and the works of V. F. and L. M. Prisnyakov on emotions such as love and fear, the study introduces a generalized information equation of emotional state. The model combines two components - subjective internal experiences and physiological manifestations - and incorporates key parameters: internal emotional tension, information density of stimuli, need satisfaction coefficient, and neural process mobility. The resulting equation reflects the interaction between cognitive and physiological aspects of emotions and corresponds to catastrophe theory, distinguishing stable and unstable emotional states. Validation with experimental data, particularly Izard's studies on infants, demonstrates good agreement with theoretical predictions. The proposed model provides a quantitative basis for analyzing emotions and suggests new directions for predicting and regulating emotional processes in psychology.

Keywords: emotional states, information theory, mathematical modeling, catastrophe theory, physiological reactions, cognitive processes.

There are many definitions of emotion, as well as approaches to studying emotional states. We will proceed from the definition that emotions are integral evaluative responses of the body to the influence of external and internal environmental factors, as well as to the results of one's own activity. Emotions manifest as subjective experiences of varying modality and intensity and are accompanied by specific motor responses of external and internal organs. Emotions are generally considered to be experienced as feelings that *motivate, organize, and guide* perception, thinking and action.

Currently, there are numerous theories of the human emotional state. All of these theories are qualitative and descriptive. A slight exception is the theory of P. V. Simonov, who believed that emotions arise as a result of a lack or excess of information necessary to satisfy a need. P. V. Simonov proposed a "formula of emotions" that defines the degree of emotional tension as the difference between the strength of the need and the magnitude of the deficit of pragmatic information necessary to achieve the goal

$$E = f[\Pi(I_n - I_c), \dots] \quad (1)$$

where E is the emotion, its degree, quality, sign; Π is the strength (type) and quality of the current need; I_n is information about the means prognostically necessary to satisfy the need, I_c is information about the means that the subject has at the time the need arises;

$(I_n - I_c)$ is an assessment of the probability (possibility) of satisfying the need based on innate and ontogenetic experience.

According to P. V. Simonov, information¹⁹ depends on:

- individual (typological) characteristics of the subject - temperament, will, motivational sphere;
- dynamic psychophysical processes, i.e., the time of manifestation of the emotional reaction (relatively rapid - affect, prolonged - feelings).

The first mathematical models of individual emotions - love and fear - were developed in 1995 by V. F. Prisnyakov and L. M. Prisnyakova. The starting point for these models was the definition of the **coefficient of the emotion** in question as a value reciprocal to the difference in information between *some ideal standard of information* stored continuously in a person's memory - for example, a life-threatening situation (in the case of describing the emotion of fear) or a person of the opposite sex (in the case of love) - and the *actual information* entering the memory at the given moment. This approach, using the theory of information processing in human memory, yielded interesting theoretical results, which, in the case of love, were supported by empirical data.

Let us use the ideas presented in these works to describe emotions *in general*.

¹⁹ We use the term "information" in a pragmatic sense, as a reflection of a set of elements that ensure the life of an individual, the subject's knowledge, his skills, the body's energy resources, the ability to organize the required actions, etc.

Based on some of the ideas of P. V. Simonov's qualitative information model of emotions, we obtain an *equation for the human emotional state*. To do this, we imagine the information set describing human emotions as consisting of two subsets. The first defines information about *internal experiences*, about the "virtual," *irrational expression of emotions*. The information set in memory about this part of emotions will be denoted by U . The second R_{ph} is information about motor processes, information *expressing emotions in physiological means* of expression: in the form of specific (motor) reactions of the face, limbs, heart (pulse), blood, tears, etc., i.e., in physiological reactions, facial expressions, posture, and actions. The total information set about the body's reactions - irrational and physiological - will be equal to

$$U_{\Sigma} = U + R_{ph} \quad (2)$$

The ratio of the total information about an individual's emotions to the total information received from outside about irritating stimuli represents a certain *coefficient of emotional amplification*. This coefficient can be considered proportional to the need $\mathcal{R}$ and inversely proportional, $\Delta I = I' - I$, to the difference between the standard of information I' about need satisfaction – for positive emotions, or about need dissatisfaction – for negative ones, and the actual value of information I received in memory. This is evident from the following two examples. If I' is information about the ideal of an individual of the opposite sex, and I is actual information about him, then the difference $\Delta I = I' - I$ determines the degree of the feeling of love - the smaller ΔI , the stronger the feeling. For the case of a feeling of fear, if I' is information about the information standard of fear, and I is information about the actual danger, $\Delta I = I' - I$ determines the degree of fear - the greater ΔI , the lesser the fear. From this it can be seen that emotions are inversely proportional to ΔI . In general, we will assume that I' is a *standard volume of information* that, in an ideal case, fully ensures the fulfillment of a stimulus, satisfying or dissatisfying for a given individual. It is determined by innate or ontogenetic experience and can change throughout a person's life. In this respect, our model differs from P.V. Simonov's model, in which ΔI is a certain estimate of the probability of need satisfaction. The two-factor theory of emotions by Schachter and Singer is close to our concepts: emotion is the result of the cognitive interpretation of diffuse physiological arousal, and cognitive labels are borrowed from personal experience or the social environment.

Based on the above, we define the *coefficient of emotions* (the coefficient of satisfaction or dissatisfaction of a need) as a value inversely proportional to the relative stimulus information $\Delta I / I'$:

$$\varepsilon = I' / (I' - I) = 1 / (1 - \nu) \quad (3)$$

Here $\nu = I / I'$ - *information density of emotional stimulus*

Taking the above into account, it can be assumed that the amount of information about the total emotions U_{Σ} is proportional to the volume of information about the event in question I , that the subject has at a certain moment in time τ (information tension). The coefficient of this proportionality, which determines the emotional amplification of information, will be equal to the product of the need coefficient $\mathcal{R}$ (which "evaluates" a specific type of stimulus), the emotion coefficient ε , and a certain coefficient μ^0 that corrects for the mobility of neural processes

$$(U + R_{ph}) = \mathcal{R} \mu \varepsilon I = \mathcal{R} I \mu / (1 - \nu) \quad (4)$$

At this stage of knowledge about the internal state of a person, we can only quantitatively evaluate information about changes in physiological (motor - facial) reactions, which, if we neglect the latent period of their appearance, we will accept as proportional to the square of the volume of information I received in the person's memory in the form of a stimulus²¹, i.e.

$$R_{ph} = a I^2 \quad (5)$$

where a is some empirical coefficient of proportionality, depending on the type of emotions and temperament of the individual.

The following considerations may serve as the basis for such a dependence. It is known that there is a genetic link between individual drives (physiological states) and individual emotions. At the biological level, emotion arises "as a sensation caused by processes occurring in the nervous and muscular systems." Emotion is also activated simultaneously by neurochemical neuromuscular, affective, and cognitive processes. The biological functions of emotions can include not only facial reactions, but also changes in acoustic characteristics (frequency of vocal cord vibrations), pantomimic manifestations, motor manifestations (movements of the head, eyes, limbs), changes in blood flow, pulse, general mobilization of muscle energy resources, etc. In our case, R_{ph} represents *information* about the physiological (motor) expression of emotions. If we accept as an axiom that external information about the event in question with a magnitude I is transformed by the body into a physiological expression of emotions with a gain coefficient proportional to I , then we arrive at the quadratic²² dependence adopted in (5). The validity of

²⁰ This assumption does not preclude the introduction of other factors, should they be found to have a significant impact on emotions, or the replacement of a direct proportional relationship with some known nonlinear one. In our first-approximation model, we limit ourselves to direct proportionality, leaving the reader the option to further complicate it.

²¹ This can be explained by the peculiarity of the autonomic nervous system, which consists of two parallel but antagonistic systems. The sympathetic nervous system prepares the

body for emotional expression, while the parasympathetic nervous system relaxes the body and restores energy reserves. Both of these systems perform internal functions and are nonlinearly dependent on the incoming stimulus.

²² It should be noted that for inanimate matter (particularly liquids and gases), a quadratic relationship is generally accepted. In humans, commands for appropriate changes are sent consciously (which is characteristic of living things), but

the adopted assumption can be demonstrated by verifying the obtained results with experiments. As we will see later, we have obtained satisfactory agreement between the calculations and some known experiments, confirming the acceptability of the adopted assumption²³.

Let us rewrite (4) taking into account (5) as follows, dividing the left and right parts term by term by the standard of information on the need under consideration I' adopted as the normalizing parameter

$$(U/I' + aI'^2/I') = I \mathcal{R} \mu / (1 - \nu) I'$$

After transformations, this equation is reduced to the following form

$$(\sigma + \alpha \nu^2)(1/\nu - 1) = \mathcal{R} \mu \equiv \gamma \quad (6)$$

Here $\sigma = U/I'$ is the parameter of internal emotional stress, $\alpha = a I'$.

We will call equation (6) the *information equation of a person's emotional state*. Its state parameters are the *potential of internal emotional tension* $1 \geq \sigma \geq 1$, the *information density of the emotional stimulus* $\nu (\leq 1)$, (or the coefficient of satisfaction (or dissatisfaction) of the need ϵ), the *price of the need* $\square$ ($0 \square \square$) and the coefficient of mobility of nervous processes $\mu (\geq 1)$. If μ of the least mobile type - the phlegmatic is taken as 1, then the other character types will have $\mu > 1$. As a measure of mobility, we can take the value reciprocal of the subjectively experienced time²⁴, the value of which for a phlegmatic person is $\tau = 1.1 \text{ sec}$ ($\mu = 1$). Then for a melancholic we get $\mu = 1.1$; for a sanguine person $\mu = 1.38$; for choleric person $\mu = 1.57$.

We will call the product $\mathcal{R} \mu = \gamma$ the *criterion of individuality of emotions*.

Here we would like to make one *remark*. We do not adhere to the point of view of some authors that if $I < I'$, then we have positive emotions, and if $I > I'$, then we have negative ones. Such an approach might be appropriate if all emotions of the same type had the same modality. In our approach, the standard of information necessary to ensure the fulfillment of the initial stimulus of satisfaction or, conversely, dissatisfaction of a given subject is the largest in volume, i.e., always $I \geq I'$. Therefore, negative emotions in this approach are determined by their meaning upon examination (for example, fear or joy), and information about negative

emotions in our model will always be positive²⁵. Positive and negative affects are considered asymmetrical. Positive emotions are poorer in physiological means of experience, more difficult to differentiate, and have fewer linguistic designations, although they occupy a disproportionately large part of subjective experiences. This point of view coincides with approaches that distinguish not between positive and negative emotions, but rather between "emotions that contribute to an increase in psychological entropy, and emotions that, on the contrary, facilitate constructive behavior."

Thus, we have 4 coordinates of the emotional state $\sigma, \nu, \mathcal{R} \mu$ (or, instead of the last two, their product γ). The parameter of the need price $\mathcal{R}$ is uniquely determined by the initial condition for a known emotional modality, taking into account the person's temperament and other individual characteristics. Therefore, in what follows, we will consider the parameters of the emotional state as the Cartesian coordinates of points in three-dimensional space σ, ν and γ . If the need price $\mathcal{R}$ is fixed, then a certain state of the individual corresponds to this set of values σ, ν and γ . We will agree to call the state determined by the set of values σ, ν and $\gamma = \mathcal{R} \mu$, the state $(\sigma, \nu, \gamma (= \mathcal{R} \mu))$. The transition of an individual's state $(\sigma, \nu, \gamma (= \mathcal{R} \mu))$ to the state $(\sigma + d\sigma, \nu + d\nu, \gamma + d\gamma)$ will be called an elementary process. The final process corresponds to the transition from the state (σ', ν', γ') to the state $(\sigma'', \nu'', \gamma'')$. Any final process can be represented as a sequential set of elementary processes. The increments $d\sigma, d\nu, d\gamma$ are independent of each other. The choice of increments determines the type of elementary process by which the subject is transferred from a given state to an adjacent state. Some of the differentials may be equal to zero.

We will call the three-dimensional space in the plane of the parameters σ, ν, γ E-space. Obviously, each state of the individual corresponds to a specific point in E-space. If we mark the points corresponding to the limiting realizable values of the parameters, then the resulting geometric locus constitutes the boundary of the region of the subject's actually realizable states.

their execution in the body is more hydrodynamic and mechanical, i.e., more "inanimate" than "living."

²³ By the way, this axiomatic approach has been widely practiced in mathematics for 2000 years.

²⁴ First introduced by B. Tsukanov

²⁵ Generally speaking, the concept of a negative emotion is meaningless. Information cannot be taken away—only the carrier of the information can be destroyed, and the information itself does not diminish when transferred from one source to another, meaning the original information set, when divided, remains the same in power.

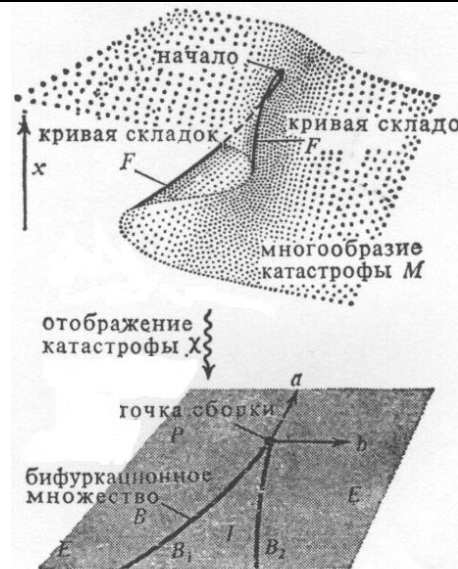


Figure 1. Geometric representation of an assembly-type disaster

There is a one-to-one correspondence between the set of points forming this bounded spatial region and the set of actually possible states of the subject. Therefore, it is necessary to speak of points representing the subject's emotional state, or representing (figurative) points. Thus, by analogy with technical disciplines, we can consider *spaces of emotional states*. In this space, states are represented by points, and quasi-static processes by lines. A process line, generally speaking, can pass through any point in the region of physically feasible emotional states of an individual.

The obtained equation (6) can be transformed to the form using known and fairly simple transformations

$$X^3 + AX + B = 0,$$

where $X = v/v - 1$,

which precisely describes the surface of an *assembly catastrophe*. This assemblage - the simplest "interesting" catastrophe (see Fig. 1) - is ubiquitous, manifesting itself in countless domains. It should be noted

that a relatively young field of analysis - catastrophe theory - has already enabled the "exact" sciences - physics, chemistry, and engineering - to derive considerable practical benefit from it. This is primarily due to the numerical answers it provides to the quantitative questions posed. In the field of psychology, a mathematical model corresponding to a catastrophe is being proposed for the first time. It is well known that catastrophe theory also allows us to distinguish between areas of stability and areas of instability. Emotions represent precisely a catastrophe, an area of instability in the human condition. Therefore, the development of mathematical models corresponding to catastrophes can serve as confirmation of the model's²⁶ validity, and its implementation opens up ways to manage a person's emotional state.

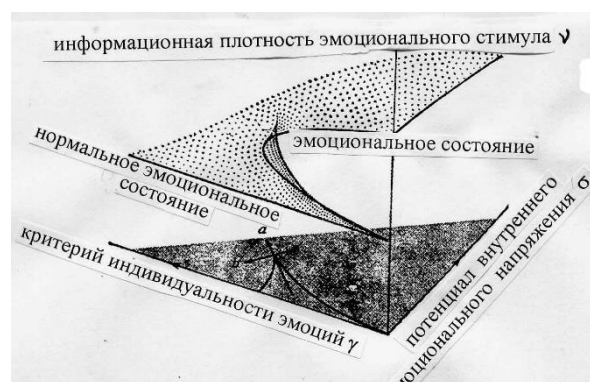


Figure 2. Assembly-type catastrophe in coordinates: potential of internal emotional stress σ - information density of emotional stimulus v - criterion of individuality of emotions γ .

²⁶ All events in our physical world are described using four coordinates, i.e., limited to a four-dimensional control space. For this case, René Thom proved a remarkable theorem: in a dynamic system with four external variables, exactly seven topologically distinct types of discontinuities can occur. Furthermore, any physical discontinuity belongs to one of these seven types. This underlies one of the most important, and

often overlooked, achievements of catastrophe theory: any model with a given number of variables must lead to one of the corresponding catastrophes. Otherwise, the model is incomplete or even incorrect, meaning that catastrophe theory can also serve as a criterion for the validity of a mathematical model.

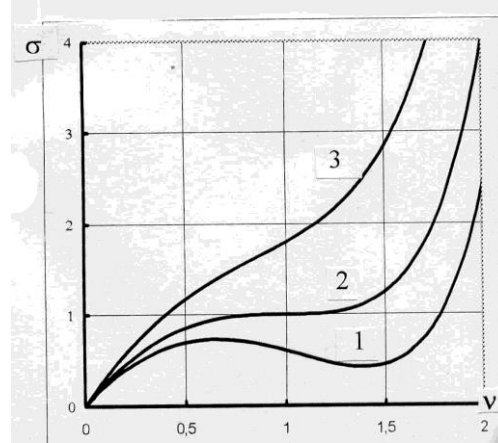


Figure 3. Dependence of the potential of internal emotional stress σ (ordinate axis) on the information density of the emotional stimulus ν (abscissa axis), for different values of the criterion of individuality of emotions γ : 1 - emotional state with physiological manifestation, accompanied by emotional release, 2 - critical state, 3 - hidden emotional state

Thus, the resulting equation (6) makes it possible to quantitatively determine the relative values of the parameters of a person's emotional state. The range of possible changes, according to our rough estimates, is $\sigma=0.1-10$; $\nu=0.05-1$, $\gamma \sim 10$ ($\alpha=1-500$). The use of relative values in our model allows us, at the initial stage, to determine, using expert assessments, the quantitative values of various initial quantities that we are not yet able to measure. However, this does not preclude the possibility of moving to absolute values of psychological variables in the future, and, moreover, to serve as a theoretical basis for experiments and to seek ways to measure the variables of the emotional process. We will demonstrate the emerging possibilities of using this equation through an example of its analysis.

First, we rewrite equation (6) in this form

$$\nu^3 - \nu^2 + [(\sigma + \gamma)/\alpha] \nu - \sigma/\alpha = 0 \quad (7)$$

The roots of this cubic equation for the information density of the emotional stimulus ν at a fixed α are a function of σ and γ . The type of curves $\sigma(\nu, \gamma)$ is shown in Fig. 3. As can be seen, three types of curves are distinguished, corresponding to such cases:

- 1) the lower curve, corresponding to three real and distinct roots of equation (7);
- 2) the middle curve – three real and equal roots;
- 3) the upper curve – one real root and two imaginary ones.

The first case occurs at low values of the need price $\mathcal{H}$ and a low coefficient of nervous system mobility μ , i.e., at low values of their product γ . As can be seen from Fig. 3, we have an unstable mode of emotional expression, which serves as a discharge of internal experiences through external motor reactions – laughter, screaming, heartbeat, tears, running, etc. Incidentally, the transition from the minimum point on the lower curve to the maximum point, apparently, corresponds to a mode in which it is easy to detect a lie using a lie detector.

The extremum points are found from the following considerations. If equation (6) is written in this form

$$\sigma = \mathcal{H}\mu/(1/\nu - 1) - \alpha \nu^2 \quad (8),$$

then to determine these points it is necessary to

consider the equation $\partial \sigma / \partial \nu = 0$:

$$\nu_{mm} (1 - \nu_{mm})^2 = \mathcal{H}\mu / 2\alpha \quad (9)$$

The function $\theta \equiv \nu_{mm} (1 - \nu_{mm})^2 = \gamma / 2\alpha$ on the left-hand side of equation (9) determines the minimum and maximum points on the curve of the dependence of the emotional tension parameter σ on the density of the emotional stimulus ν_{mm} , corresponding to the extreme values (see Fig. 4). The value of these points is located at the intersection points of the graph of the function θ with the values of $\gamma / 2\alpha$. From examining the graph in Fig. 4, it is evident that with a decrease in the product $\mathcal{H}\mu = \gamma$, the minimum point shifts toward a decrease in the value of the density of the emotional stimulus ν , and the maximum point shifts toward an increase in its value, i.e., "motor emotional manifestation (discharge) of physiological excitation" occurs in a larger range of ν , in a larger range of change in stimulus information.

If the maximum point of this function at a certain value of the density of the emotional stimulus ν_{min} , corresponding to the minimum of emotional tension σ , coincides with the value ν_{max} , corresponding to the maximum of emotional tension σ , then our zigzag lower curve degenerates into a certain "critical" curve without a maximum and minimum (the middle curve), which are compressed to a certain critical point with coordinates σ_c ; ν_c and γ_c . This second case of the solution of equation (7) with three real and equal roots corresponds to the following critical values of the independent variables we use:

$$\sigma_c = \alpha/27; \nu_c = 1/3; \gamma_c = (\mathcal{H}\mu)_c = 8\alpha/27 \quad (10)$$

Note that the critical value of the emotional stimulus density is equal to $\nu_c = 1/3$, i.e. the transition to the critical curve occurs when the magnitude of the emotigenic stimulus reaches one-third of the emotion standard value. Obviously, curve 2 separates the region of the unstable process (curve 1) from the stable one (curve 3).

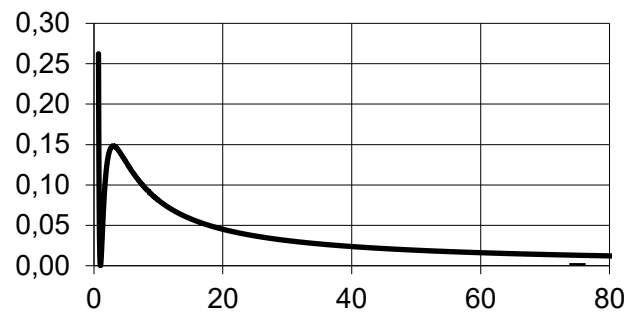


Figure 4. Graph of the dependence of the function $\theta = v_{mm} (1 - v_{mm})^2$ (ordinate axis) on $v_{min/max}$ (abscissa axis), corresponding to the minimum σ – left ascending curve, and the maximum σ – right descending curve.

The third case of the process of increasing emotional tension depending on the influx of external stimulus information occurs with elevated values of the emotion individuality criterion $\gamma = (\mathcal{R}\mu) > \gamma_c = (\mathcal{R}\mu)_c$. Clearly, higher values of the emotion individuality criterion γ correspond to the most stable temperaments and subjects with the most stable nervous system mobility. This case is characterized by a negligible expression of emotions through physiological mechanisms. This allows us to neglect the last term in equation (8) and write the following formula for the increase in emotions in the case of elevated values of the parameter γ :

$$\sigma = \mathcal{R}\mu / (1/\nu - 1) \quad (11)$$

or

$$\sigma (1/\nu - 1) = \mathcal{R}\mu \quad (12)$$

This equation shows that for large values of the product $\mathcal{R}\mu$, the curves $\sigma = f(\nu, \mathcal{R}\mu = \text{const})$ are hyperbolas that have one intersection point with the horizontal line and, as a result, one real and two imaginary roots. There are no extrema points on this curve.

To verify the theoretical results obtained, we will use known (and, it must be said, few) experiments described by variables of emotional expression that allow

calculations in the plane of the parameters of the proposed theory. Emotions of the same type are more difficult to identify in an adult than in a child. Therefore, measurements of physiological parameters determining emotional processes in four-and-a-half-month-old children, carried out by Izard, are of particular value. In these experiments, the emotions of anger and interest were studied by measuring heart rate and videotaping the child's facial reactions. The basis for processing graphs suitable for their comparison with calculations in the plane of the used parameters was the graph shown in Fig. 5, in the form of changes in heart rate f during the experience of the emotions of anger and interest. We will represent these experimental data in the plane of variables: the potential of internal emotional tension σ (ordinate axis) - the information density of the emotional stimulus ν (abscissa axis). It is obvious that the increase in heart rate $\Delta f = f - f_0$ is proportional to the magnitude of emotions ($f_0 = 145$ beats/min - heart rate without emotions).

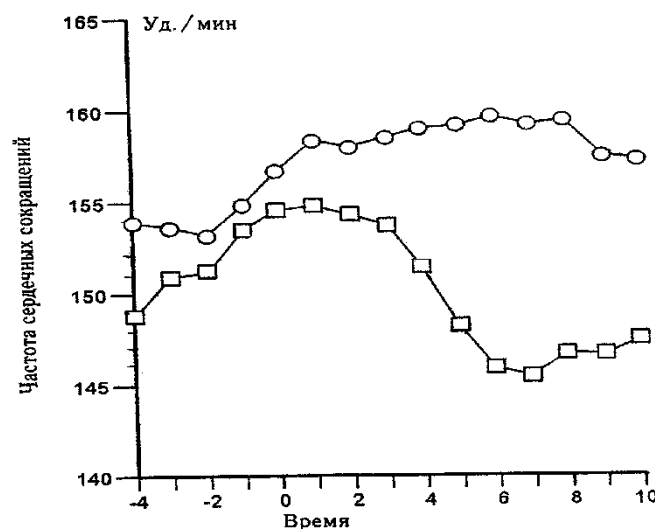


Figure 5. Features of the functioning of the cardiovascular system in children aged four and a half months during their experience of the emotion of interest (1) and the emotion of anger (2). 0 the beginning of facial expression

If we take as a normalizing parameter the possible permissible range of deviation of the heart rate in the

case of emotional stress $f' = 15$ beats/min, then this relative change in the heart rate can be considered equal

to another relative value - the potential of internal emotional stress²⁷, i.e. $\sigma = U/I \approx \Delta f/f'$. If we accept that during the period of emotional influences the rate of incoming information from the outside $\dot{R} = \text{const}$, then $\tau = I/\dot{R}$ и $\tau' = I'/\dot{R}$, i.e. the information density of the emotional stimulus $\nu = I/I' = \tau/\tau'$. The value of τ' , which determines the value proportional to the information standard I' , is taken to be $\tau' = 20$ sec for the case of children experiencing the emotion of interest, and $\tau' = 50$ sec for the emotion of anger. These values were selected after numerous calculations as the values that provide the best agreement with the experimental data. The value of the constant $\alpha = a I'$ is also unknown. Numerical calculations have shown that for experiences of the emotion of interest $\alpha = 40$, for emotions of anger $\alpha = 38$. Again, we see the advantage of introducing rel-

ative quantities – the proportionality constant α is a dimensionless quantity. Moreover, due to its zero dimension, it can be expected to change little for other types of emotions and other experimental conditions.

Now, regarding the value of the emotion individuality criterion $\gamma = \mathcal{R}\mu$. Determining it requires independent research into both the value of the need $\mathcal{R}$, and the neural process mobility coefficient μ , which generally presents no particular difficulties. In our calculations, we adopted $\gamma = 10$ as the value providing the best agreement between the calculations and experimental data²⁸. However, strictly speaking, the question of this value remains open. We note that the obtained numerical values of the normalizing variables can, as a first approximation, be used to predict the development of human emotions using an equation like (6).

Table 1.

Processing of experimental data by Izard and calculations according to (6) for the case of a child experiencing the emotion of interest.

$\Delta \tau, \text{sec}$	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
τ, sec	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ν	0	0.0 5	0.1 5	0.15 5	0.2 5	0.2 5	0.3 5	0.3 5	0.4 5	0.45 5	0.5 5	0.55 5	0.6 5	0.65 5	0.7 5
$f, \text{beats/min}$	148. 5	151	151. 5	153. 5	154. 5	155	154. 5	154	152	147. 5	146	145. 5	146. 5	146. 5	147. 5
$\Delta f, \text{beats/min}$	3.5	6	6.5	8.5	9.5	10	9.5	9	7	2.5	1	0.5	1.5	1.5	2.5
σ_{exp}	0.23	0.4	0.43	0.57	0.63	0.6 7	0.63	0.6	0.4 7	0.17	0.0 7	0.03 3	0.1	0.1	0.17
σ_{calc}	0	0.4 3	0.71	0.86	0.9	0.8	0.7	0.5	0.3	0.1	0	0.12	0.6	0.7	

Table 2.

Processing of Izard experimental data and calculations according to (6) for the case of a child experiencing the emotion of anger.

$\Delta \tau, \text{sec}$	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
τ, sec	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ν	0	0.02	0.04	0.06	0.08	0.1	0.12	0.14	0.16	0.18	0.2	0.22	0.24	0.26	0.28
$f, \text{beats/min}$	154	153.5	153	155	157	158	157.5	158	159	159.5	160	159.5	159.8	157.5	157
$\Delta f, \text{beats/min}$	9	8.5	8	10	12	13	12.5	13	14	14.5	15	14.5	14.8	12.5	12
σ_{exp}	0.6	0.57	0.53	0.67	0.8	0.87	0.83	0.87	0.93	0.97	1	0.97	0.99	0.83	0.8
σ_{calc}	0	0.185	0.36	0.5	0.62	0.73	0.82	0.89	0.9	1	1	0.97	0.96	0.94	0.91

The results of the calculations carried out using formula (6) and the processing of the experimental data are presented in Tables 1 and 2, and in Figs. 6 and 7 (point $\Delta \tau = 0$ corresponds to the beginning of the facial expression).

An examination of Figs. 6 and 7 confirms the satisfactory agreement between the theoretical results and the experimental data. The question of explaining the initial drop in heart rate for the case of anger remains open (see curve 1 in Fig. 7 for $\tau = 0-2$). Naturally, we are aware that in the calculations we selected some parameters in such a way as to obtain satisfactory agreement

between the calculations and experiments. But there is every reason to consider these quantities - $f', f_0, \tau', \gamma, \alpha$ - to be sufficiently conservative, in particular for emotions of one type, and therefore they can serve as a primary basis for refining the equation of emotional state as applied to a specific type of emotion, and for predicting emotional processes of various types. In this case, the meaning of the variables included in (6) and the numerical coefficients should naturally correspond to the type of emotion under consideration.

²⁷ That is, we accept a direct proportional dependence $I' \sim f'$ (this conclusion is another illustration of the usefulness of representing variables in relative form).

²⁸ Again, using relative parameters allows you to select control parameters without much difficulty.

So, in the case of *fear*, U is the internal experience of fear, dread, R_{ph} is the physiological reaction to information expressing fear - flight, screaming, etc., I' is the information standard of the type of fear in question - an attack by an animal, a robber, an emergency, natural disasters, etc., ε is the fear coefficient equal to $\varepsilon = I'/(I' - I) = 1/(1 - \nu)$; I is real information about fear; $\mathcal{R}$ is the price of the need (danger to life, to health, to loved ones, to a career, etc.); μ is the coefficient of mobility of nervous processes. With this content of variables, we

arrive at the equation of the state of fear in the form (6). For the case of *anger*, U is the internal experience of irritation, rage, R_{ph} is the physiological manifestation (discharge) of anger - shouting, threats, facial expressions, etc., I' is the information standard of physical or psychological lack of freedom, ε is the anger coefficient, equal to $\varepsilon = I'/(I' - I) = 1/(1 - \nu)$; I is real information about the restriction of freedom; $\mathcal{R}$ is the price of the need for freedom of human activity to achieve the desired goal.

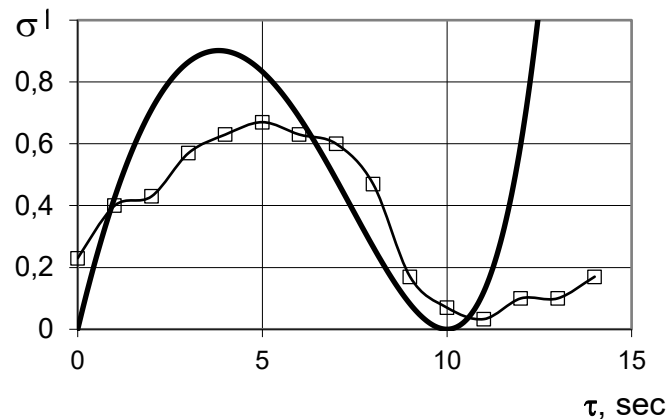


Figure 6. Comparison of Izard's experimental data on the emotional state of a 4.5-month-old child during the experience of the emotion of interest with calculations using formula (6) in the plane of parameters: potential of internal emotional tension of interest σ (ordinate axis) - information density of the emotional stimulus ν (abscissa axis), with the value of the criterion of individuality of emotions $\gamma=10$; 1 - experimental data, 2 - calculation

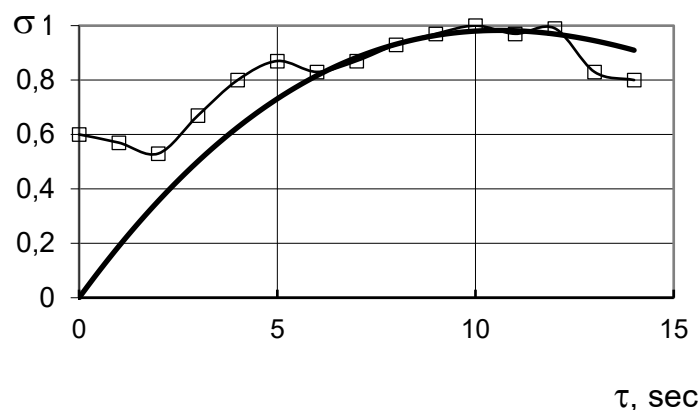


Figure 7. Comparison of Izard's experimental data on the emotional state of a 4.5-month-old child experiencing the emotion of anger with calculations using formula (6) in the plane of parameters: potential of internal emotional tension of anger σ (ordinate axis) - information density of the emotional stimulus ν (abscissa axis), with the value of the criterion of individuality of emotions $\gamma=10$; 1 - experimental data, 2 - calculation.

Therefore, if we put this meaning into the specified variables, then we arrive at the equation of the state of anger in the form (6).

Thus, the presented theoretical analysis makes it possible to control the course of emotional processes using the value of need $\mathcal{R}$ and the nervous system's mo-

bility coefficient μ . This model is only a first approximation, and changes in the independent variables used require further study, in particular the development of a method for their quantitative determination. This task is beyond the scope of this work.

TECHNICAL SCIENCES

ASYMPTOTIC ATTAINMENT OF THE K.E. SHANNON ENERGY LIMIT VALUE WITH A SYNCHRONOUS ORTHOGONAL CODE

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АСИМПТОТИЧЕСКОЕ ДОСТИЖЕНИЕ ПРЕДЕЛЬНОГО ЗНАЧЕНИЯ К.Э. ШЕННОНА ПО ЭНЕРГЕТИКЕ СИНХРОННЫМ ОРТОГОНАЛЬНЫМ КОДОМ

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Abstract

This article proves that the synchronous orthogonal code OK2048 provides an asymptotically limiting minimum $\frac{E_{bit}}{J_0}$ ratio in a continuous Gaussian channel at an information rate equal to the channel capacity. The decoding complexity is determined by the extremely sparse matrix of this orthogonal code.

Аннотация

В статье доказано, что синхронный ортогональный код ОК2048 обеспечивает асимптотически предельное минимальное отношение $\frac{E_{bit}}{J_0}$ в непрерывном гауссовском канале при скорости передачи информации, равной пропускной способности канала. Сложность декодирования определяется предельно разреженной матрицей этого ортогонального кода.

Keywords: continuous Gaussian channel with AWGN, PPSU codes, synchronous orthogonal code, frequency efficiency, signal separability.

Ключевые слова: непрерывный гауссовский канал с АБГШ, коды ППСУ, синхронный ортогональный код, частотная эффективность, разделимость сигналов.

Введение

Целью статьи является рассмотрение принципов построения системы передачи информации на основе синхронного ортогонального кода (ОК), являющегося на сегодняшний день лучшим кодом плотнейшей поверхности – сферической укладки (ППСУ). Сложность декодирования этого ОК определяется матрицей Адамара, или диагональной матрицей, обладающими уникальным свойством предельного разрежения вплоть до двух, или до одного ненулевого элемента в каждой строке задающей матрицы при любой длине существования ОК.

Прямая радиопередача

Прямая линия (Forward Link) строится по схеме синхронного ОК с одновременной и синхронной передачей всех n_{OK} каналов строго при нулевом сдвиге начала каждой кодовой комбинации относительно начального момента времени передачи синхронного ОК (необходимое условие ортогональности кода). В силу ортогональности все каналы синхронного ОК являются взаимно линейно независимыми и, как следствие, разделимы на приёме. Кодирование устройства синхронного ОК кодируется внешним потоком равновероятных тричных символов со значениями $\{\pm 1, 0\}$ (см. рис. 1).

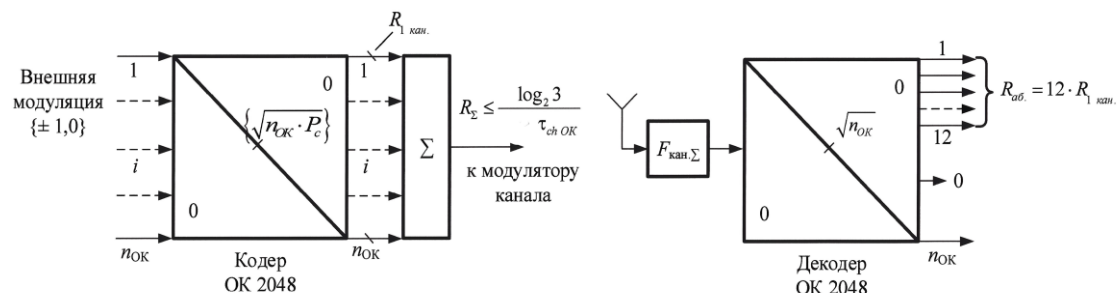


Рисунок 1 – Структурная схема прямой радиопередачи (Forward link): в соте 170 абонентам отводится по 12 информационных каналов и 1 (служебному) абоненту отводится 8 каналов

В этом случае суммарная скорость передачи

$$R_{\Sigma} = \frac{\log_2 3}{\tau_{ch_OK}}, \quad (1)$$

$$R_{1\text{кан.}} = \frac{R_{\Sigma}}{n_{OK}}. \quad (2)$$

$$R_{аб.} = 12 \cdot R_{1\text{кан.}} \quad (3)$$

Результаты расчёта скорости передачи представлены в таблице 1.

Таблица 1.

Расчёт значений скорости передачи и требуемой полосы частот в прямой радиолнии

№	Наименование параметра	Расчётные значения	Примечание
1	R_{Σ}	361, 37 Мбит/с	$\max f_{\text{ТИ}_{MS}} = 912,0 \text{ МГц},$ $\max f_{\text{ТИ}_{OK}} = 228,0 \text{ МГц}$
2	$R_{1\text{кан.}}$	0,1765 Мбит/с	
3	$R_{аб.}$	2,1174 Мбит/с	
4	$F_{\text{кан.}\Sigma}$	7924,8 МГц	

В Forward link синхронный ОК передаёт информацию без внешнего помехоустойчивого кодирования. В этой линии с синхронным ОК взаимные помехи отсутствуют, канал – непрерывный гауссовский.

$$q_{bitOK} = \frac{Q_{err.dX}}{n_{OK}} \leq (N_d + (V_{\text{акт.}} - 1)) \cdot Q\left(\sqrt{\frac{P_c}{\sigma^2}} \cdot d_X\right) \cdot \frac{d_X}{n_{OK}}, \quad (4)$$

где $(n_{OK}, V_{\text{акт.}}, d_X, N_d)$ – параметры синхронного

ОК, $Q(x) = \frac{1}{\sqrt{2\pi}} \int_{\frac{x}{\sigma}}^{\infty} e^{-t^2/2} \cdot dt$ – интеграл вероятности ошибки.

При заданной вероятности ошибки декодирования q_{bitOK} по вып. (4) рассчитывается требуемое

отношение $\frac{P_c}{\sigma^2} = \frac{X^2}{d_X}$. Расчёт помехоустойчивости

выполняется при скорости передачи, равной пропускной способности канала. В этом случае $\frac{E_{bit}}{J_0} = \frac{P_c}{\sigma^2} \cdot \gamma_{\text{кан.}\Sigma}$, где частотная эффективность канала $\gamma_{\text{кан.}\Sigma} = \log_2(1 + \frac{P_c}{\sigma^2})$.

При $F_{\text{кан.}\Sigma} \rightarrow \infty \lim \frac{E_{bit}}{J_0} = \lim \frac{\frac{P_c}{\sigma^2} \cdot \ln 2}{\ln(1 + P_c/\sigma^2)} = \ln 2 = -1,59 \text{ дБ} [1]$.

Таким образом, выбор максимально допустимого значения частотной эффективности широкополосной системы, равным частотной эффективности канала, $\gamma_{\text{сист.}} = \frac{R}{F_{\text{кан.}\Sigma}} = \gamma_{\text{кан.}\Sigma}$, минимизирует

требуемое отношение $\frac{E_{bit}}{N_0}$.

Результаты расчёта требуемых отношений $\frac{E_{bit}}{N_0}$ для синхронного ортогонального кода ОК- 2048 при его приёме в непрерывном гауссовском канале приводятся в таблице 2.

Таблица 2.

Расчёт помехоустойчивости синхронного ОК-2048 в непрерывном канале с АБГШ

$q_{bit \Sigma}$	$(P_c / \sigma^2)_{вх.ОК}$	$\gamma_{\text{кан.}\Sigma}$	$\frac{E_{bit}}{N_0} \text{ дБ}$
10^{-3}	0.0234	0.0334	- 1,541
10^{-5}	0,0321	0,0456	- 1,523
10^{-7}	0,0409	0,0578	- 1,504
10^{-10}	0,0541	0,0760	- 1,477

Требуемая полоса частот также рассчитывается из условия согласования по скорости передачи с пропускной способностью непрерывного гауссовского канала.

$R_{\Sigma} = \frac{\log_2 3}{\tau_{ch_OK}} = C_{\Sigma} = \frac{1}{l_{\Sigma} \cdot \tau_{ch_OK}} \cdot \gamma_{\text{кан.}\Sigma}$, $l_{\Sigma} = \frac{\gamma_{\text{кан.}\Sigma}}{\log_2 3}$ – коэффициент согласования.

$$F_{\text{кан.}\Sigma} = \frac{1}{l_{\Sigma} \cdot \tau_{ch_OK}} = \frac{\log_2 3}{\gamma_{\text{кан.}\Sigma} \cdot \tau_{ch_OK}} = \frac{R_{\Sigma}}{\gamma_{\text{кан.}\Sigma}} \text{ при}$$

скорости передачи $R_{\Sigma} = C$.

Результаты расчётов R_{Σ} и $F_{\text{кан.}\Sigma}$ в прямой радиолнии при $q_{bit \Sigma} = 10^{-5}$ приводятся в таблице

1. В статье анализируются предельные возможности системы. При широкой полосе частот радиоканала в нём обеспечивается высокая помехозащищённость против искусственных помех. Требуемое значение полосы частот $F_{\text{кан.}\Sigma}$ можно уменьшить выбором меньших значений тактовой частоты. При этом достигнутые значения отношения $\frac{E_{bit}}{N_0}$ остаются без изменения.

По мнению автора лучший результат помехоустойчивого кодирования ($\frac{E_{bit}}{N_0} = 0,7 \text{ дБ}$ при

$q_{bit} = 10^{-5}$), полученный Claude Berrou и его соавторами для Turbo – Code на основе свёрточного

кода с кодовым ограничением $K = 5$, а также лучшие результаты, достигнутые длинными LDPC кодами [2], получены для этих кодов с выбором относительной скорости кодирования $r_c = 1/2$ поиском “вслепую”. Такие неширокополосные коды не в состоянии достигнуть даже отношения $\frac{E_{bit}}{N_0} = 0\text{дБ}$.

В работах автора [3, 4] и, в частности, в приведённых выше расчётах (см. табл.2) доказываем, что при скорости передачи информации $R_\Sigma = C_\Sigma$ предельно минимальные отношения $\frac{E_{bit}}{N_0}$ достигаются в широкополосной системе с высокой помехоустойчивостью. Этим требованиям удовлетворяют симплексные, биортогональные и синхронные ортогональ-

ные коды, являющиеся кодами плотнейшей поверхностно – сферической укладки [5, 6].

В работах [7, 8] приводится с описанием конкретная каскадно – кодовая конструкция со скоростью передачи $1,3/\tau_{ch}$ на основе синхронного ОК128 и внешнего троичного помехоустойчивого кода с блоковой длиной 128. Согласно [8], при $q_{bit} = 10^{-5}$ требуется обеспечить $\frac{E_{bit}}{N_0} = -1,11\text{ дБ}$.

Обратная радиолиния

Обратная радиолиния может быть спроектирована по образцу радиointерфейса стандарта IS – 95. В этом случае выполняется равенство длительностей сигналов

$$n_{OK} \cdot \tau_{ch,OK} = (D_{\text{адрес}MS} + 1) \cdot \tau_{ch,MS} \quad (5)$$

при максимальной тактовой частоте сигналов генератора “Адрес MS” (она же тактовая частота радиоканала).

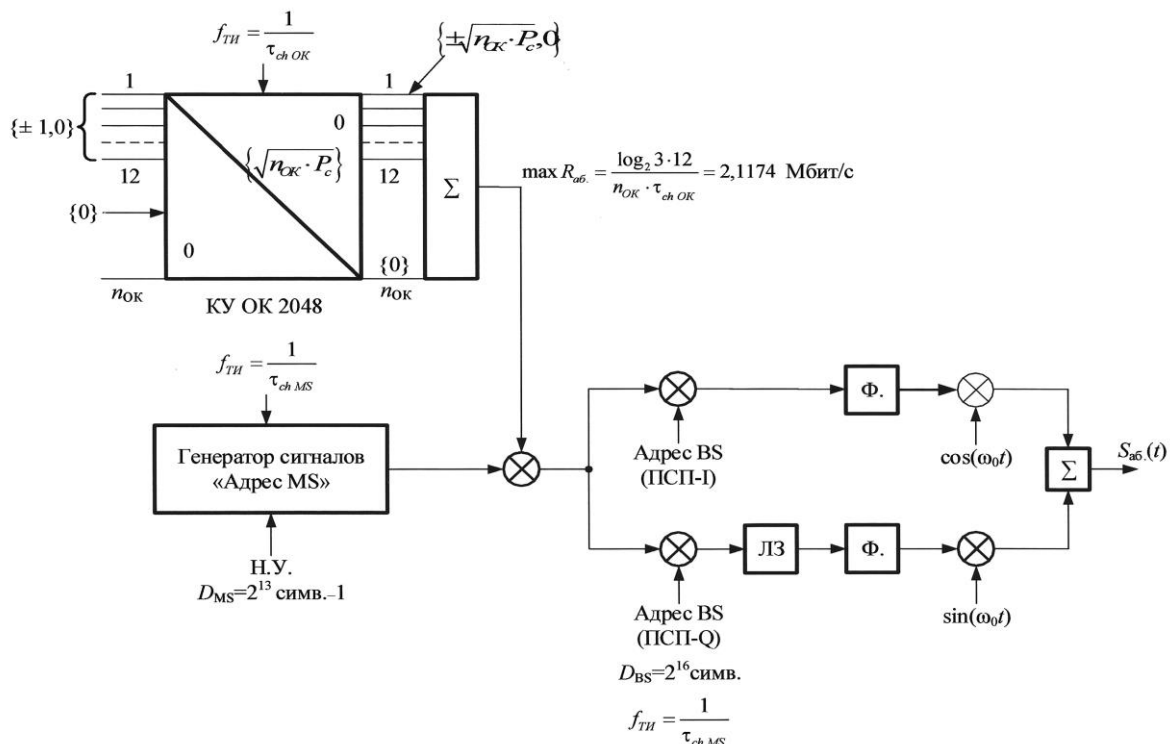


Рисунок 2. Структурная схема обратного канала абонента.

$$f_{TH, MS} = \frac{1}{\tau_{ch, MS}} = \frac{D_{\text{адрес}MS} + 1}{n_{OK} \cdot \tau_{ch, OK}} = \frac{8192}{2048 \cdot \tau_{ch, OK}} = \frac{4}{\tau_{ch, OK}}. \quad (6)$$

Согласно [9], уровень микроэлектроники на российском рынке на сегодняшний день определяется технологией изготовления 40 нм, что задаёт максимальную тактовую частоту, равной 912,0 МГц при нормальных условиях эксплуатации. Тогда при $f_{TH, MS} = f_{TH, BS} = 912,0 \text{ МГц}$ $\max f_{TH, OK} = \frac{1}{\tau_{ch, OK}} = 228,0 \text{ МГц}$.

Основную роль синхронизации в обратной радиолинии выполняет сигнал “Адрес BS” с длительностью $T_{\text{адрес}BS} = (2^{16} - 1) \cdot \tau_{ch, BS}$. Передние фронты сигналов синхронного ОК и генератора сигналов “Адрес MS” в обратной радиолинии жёстко привязаны к переднему фронту сигнала “Адрес BS”. При этом на длительности этого сигнала размещаются одновременно 8 сигналов синхронного ОК и 8 сигналов “Адрес MS” (см. рис. 2).

Каждому из 170 групповых абонентов в обратной радиолинии отводится по 12 каналов. Рассмотренное выше обоснование выбора тактовых частот учтено при описании Forward Link.

Абоненты в обратной радиолинии работают в асинхронном режиме. Основной задачей является расчёт максимально допустимого числа одновременно работающих на передачу (в сторону “своей” BS) абонентов и скорости передачи абонента $R_{аб.}$. При спектральной плотности мощности теплового шума

$N_0 = 290^0 \cdot 1,380662 \cdot 10^{-23} \frac{W}{Hz} = 4,004 \cdot 10^{-21} \frac{W}{Hz}$ воспользуемся методикой расчёта фирмы Qualcomm (без учёта мощности теплового шума $\sigma^2 = N_0 \cdot F$)

$$(M-1) = \frac{C_p \cdot \eta_p}{\left(\frac{E_{bit}}{J_0}\right)_{OK} \cdot \nu_f \cdot (1+f)}, \quad (7)$$

где M – число обратных каналов в секторе соты,

$S = 3$ – число секторов приёмной антенны на входе BS,

$$G_p = \frac{2 \cdot F_{кан. MS}}{R_{аб.}} = \frac{B_w}{R_{аб.}} - \text{выигрыш обработки,}$$

η_p – коэффициент эффективности управления мощностью передатчиков абонентов в обратной радиолнии,

$$E_{bit_OK} = \frac{P_c}{R_{аб.}} - \text{требуемый абонентом расход энергии на бит,}$$

$J_0 = \frac{(M-1) \cdot \gamma_f \cdot P_c}{F}$ – спектральная плотность мощности взаимных помех,

ν_f – коэффициент речевой активности,

f – коэффициент влияния передающих устройств BS соседних сот.

Расчёт энергетике наземных радиолний выполняется при условии работы как в обратной, так и в прямой радиолнии с обязательным наличием Rake receiver в точках приёма.

Для расчёта помехоустойчивости в информационном подканале абонента используем выр. (4) при $V_{акт.} = 12$ каналов. Тогда, например, при вероятности $q_{бит_аб.} = 10^{-5}$ требуемое отношение

$$\frac{P_c}{\sigma^2} = 0,0308, \quad \text{частотная эффективность}$$

$$\gamma_{кан.аб.} = 0,043764 \text{ бит} / (с \cdot Гц), \text{ а}$$

$$\left(\frac{E_{bit}}{N_0}\right)_{OK} = -1,5257 \text{ дБ.} \quad (8)$$

При оценке остальных параметров в выражении (7) значениями:

$$B_w = 2F_{кан. MS} \cong \frac{1}{\tau_{ch, MS}} = 912,0 \text{ МГц (информация в служебном подканале абонента не передаётся, } R_{MS} = 0), \eta_p = 0,8, (M-1) = 682 \text{ приёмных}$$

канала при трёхсекторной антенне на входе BS, $\nu_f = 0,43, (1+f) = 1,668$ значение скорости передачи группового абонента $R_{аб.} = 2,12 \cdot 10^6$ бит/с.

При этом значении $R_{1кан.} = \frac{R_{аб.}}{12} = 0,1767 \cdot 10^6$ бит/с.

В итоге $R_\Sigma = R_{аб.} \cdot 170 + R_{1кан.} \cdot 8 = 361,8 \cdot 10^6$ бит/с.

Число каналов, отводимых одному абоненту, $N_{кан.1аб.} = \frac{R_{аб.} \cdot n_{ок}}{R_\Sigma}$, где скорость передачи $R_{аб.}$ определяется выражением (7). В данной работе принято $N_{кан.1аб.} = 12$ ортогональных каналов. Число групповых абонентов в обратной радиолнии равно $N_{аб.} = \frac{2048}{12} = 171$ абонент $\left(57 \frac{\text{абонентов}}{\text{сектор соты}}\right)$.

Требуемые полосы частот $F_{аб.} = \frac{R_{аб.}}{\gamma_{кан.аб.}} = F_{1кан.} = 48,44$ МГц.

Максимальная скорость передачи абонентской станции может быть определена из условия согласования с каналом по скорости, т.е. при $\max R_{аб.} = C_{аб.}$.

$$\max R_{аб.} = F_{аб.} \cdot \log_2 \left(1 + \frac{P_c}{\sigma}\right) = 2,12 \cdot 10^6 \text{ бит/с.}$$

Но, если диагональную матрицу, задающую ортогональный код, заменить на матрицу

Адамара, то скорость передачи абонента $R_{аб.}$ снижается в $\log_2 n_{OK} = 11$ раз.

Заметим, что начальная установка генератора сигналов “Адрес MS” однозначно связана с номером группы абонента.

При точном, более сложном расчёте скорости передачи абонента $R_{аб.}$ (с известным значением мощности сигнала $P_c = 5,6235 \cdot 10^{-14}$ W и требуемым суммарным отношением $\frac{E_{bit}}{I_t} = 0,7 = -1,549$ дБ) синхронный ОК-2048

обеспечивает скорость абонента $R_{аб.} = 2,0 \cdot 10^6 \text{ бит} / \text{с.}$

Ширина всей рабочей полосы Reverse link $B_w = 2F \approx \frac{1}{\tau_{ch}} = 912$ МГц выбирается из

условия периодической передачи в канал коротких чипов BS. Точность синхронизации в обратной линии определяется также этим сигналом, $\Delta \tau \cdot D_{BS} = 0,1 \cdot \tau_{ch}$, т.е. относительная погрешность подстройки по времени $\frac{\Delta \tau}{\tau_{ch}}$ не должна превышать $\frac{0,1}{2^{16}-1} = 1,526 \cdot 10^{-6}$.

В заключение выполним расчёт помехоустойчивости в информационном подканале абонента в направлении MS – BS. Канал – непрерывный гауссовский с суммарной мощностью аддитивных помех $(\sigma^2 + J) = N_0 \cdot F + (M-1) \cdot \nu_f \cdot P_c$.

$$Q_{ош.ОК} \leq (N_d + (V_{акт.} - 1)) \cdot Q\left(\sqrt{\frac{E_{bit}}{I_t}} \cdot \gamma_{кан.ОК} \cdot d_{x_OK}\right). \quad (9)$$

Подставляя числовые значения, получим $Q_{ош.ОК} \leq 2058 \cdot Q(\sqrt{0,7 \cdot 0,043764 \cdot 1024}) = 2058 \cdot 1,072 \cdot 10^{-8} = 2,2062 \cdot 10^{-5}$. Согласно выр. (8), передача информации в обратном канале

абонента только с шумовой аддитивной помехой σ^2 выполнялась при $Q_{\text{ош.ОК}} = 2 \cdot 10^{-5}$.

Литература

1. Claude Elwood Shannon. Collected papers. Ed. by H.J.A. Sloane, Aaron D.Wyner. IEEE Press. Piscataway, N.J., USA. 1993, 924 p.
2. The Best of the Best. Ed. by William H. Tranter, Desmond P. Taylor, Rodger E. Ziemer, Nicholas F. Maxemchuk, Jon W. Mark. IEEE Press. A John Wiley & Sons, Inc., Publication . 2007, 692 p.
3. Кузнецов В.С., Кузнецов В.В. Нерешённые проблемы в области передачи информации и связи. - М.: Горячая линия – Телеком, 2016. – 60 с.
4. Кузнецов В.С. Асимптотические решения проблемы Шеннона в непрерывном гаусс - совском канале. – М.: Горячая линия – Телеком, 2021, - 72 с.
5. Кузнецов В.С. Асимптотическое достижение границы К.Э. Шеннона с применением кодов

плотнейшей поверхностью – сферической укладки. - М.: Системы синхронизации, формирования и обработки сигналов. № 1 – 2023, с. 62 – 67.

6. Кузнецов В.С. Синхронные ортогональные коды. – М.: Системы синхронизации, формирования и обработки сигналов. № 1 – 2024, с. 26 – 29.

7. Патент РФ на изобретение № 2834691. Способ помехоустойчивого кодирования троичным кодом с широкополосной передачей данных. Авторы: Кузнецов В.С., Волков А.С., Солодков А.В., Лоос В.В. Приоритет изобретения 14 июня 2024 г. Дата гос. регистрации 12 февраля 2025 г.

8. Kuznetsov V., Volkov A., Solodkov A., Loos V. High – Speed Ternary Error Correction Code // 2025 Conference Young Researchers in Electrical and Electronic Engineering (2025 ElCon), St. Petersburg Electrotechnical University “LETI”, 2025, January 28 – 29, St. Petersburg, Russia. – p. 1694 – 1697.

9. Каталог для систем связи и радиолокации. – М.: “ЭЛВИС “, www.elvees.ru, 2025, 24 с.

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