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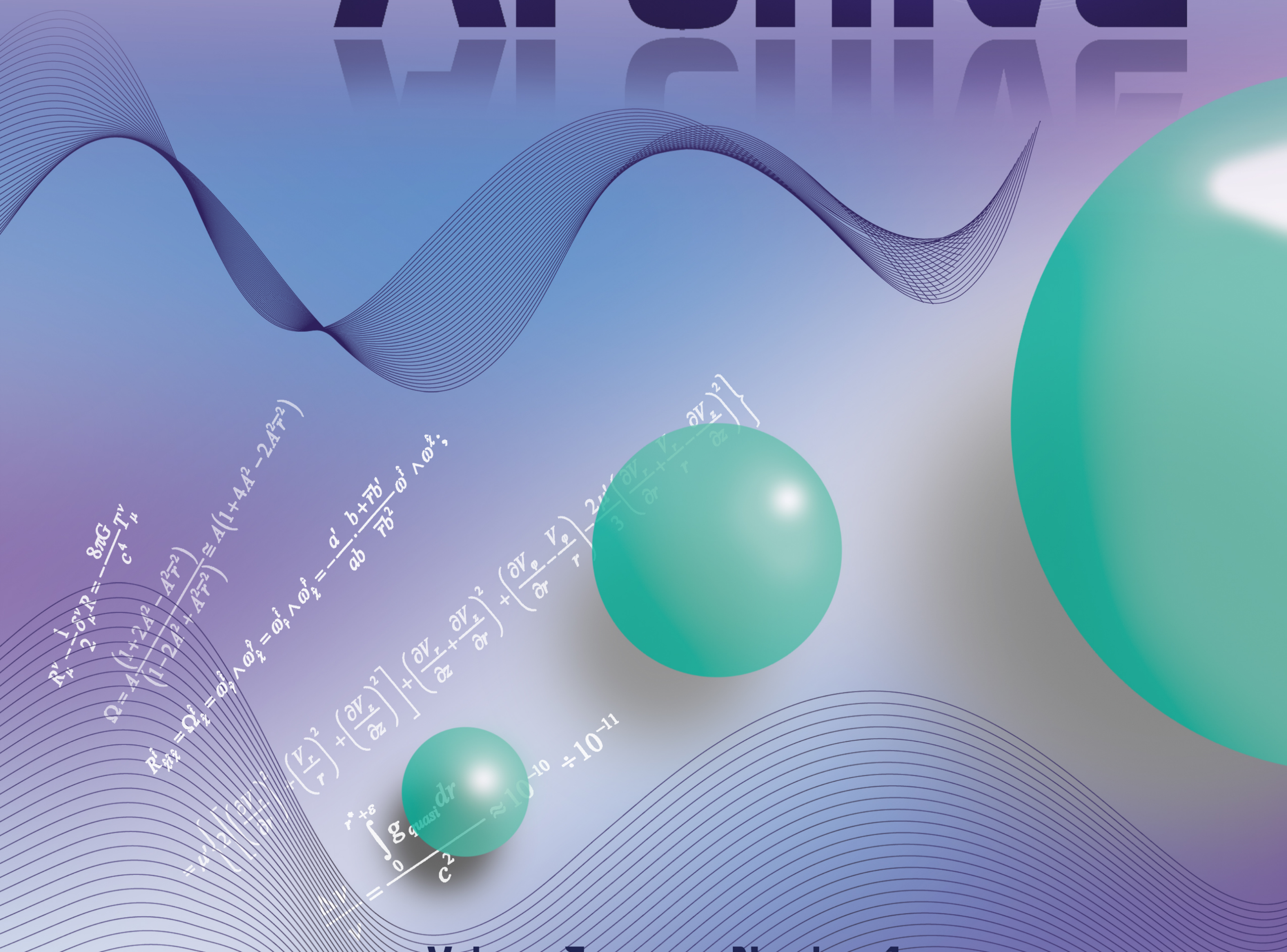

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# FROM EINSTEIN TO STOBBE-SAUTER PHOTOEFFECT AND RELATED PROBLEMS

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Abstract

We consider photoelectric effect including phonon emission and the initial dressed photon. We include the polychromatic form of the photoeffect, and the photoeffect in the two-dimensional electron gas in magnetic field. We consider the nonrelativistic and relativistic quantum theory of ionization as the extension of the old theory of photoeffect. As the related problem, we calculate the H-atom in the black body sea, which is equivalent to the Gibbons-Hawking thermal bath. We include the problem of the velocity of sound in the relic photon sea, thermal Casimir effect, dielectric crystal immersed in the black-body sea and the Cherenkov radiation in the two-dimensional dielectric medium.

## 1 Introduction

The photoelectric effect is a quantum electromagnetic phenomenon in which electrons are emitted from matter after the absorption of energy from electromagnetic radiation. Frequency of radiation must be above a threshold frequency, which is specific to the type of surface and material. No electrons are emitted for radiation with a frequency below that of the threshold. These emitted electrons are also known as photoelectrons in this context. The photoelectric effect was theoretically explained by Einstein in his paper in 1905 (Einstein, 1905; 1965) and the term "light quanta" called "photons" was introduced by chemist G. N. Lewis, in 1926. Einstein writes (Einstein, 1905; 1965): *In accordance with the assumption to be considered here, the energy of light ray spreading out from point source is not continuously distributed over an increasing space but consists of a finite number of energy quanta which are localized at points in space, which move without dividing, and which can only be produced and absorbed as complete units.*

It is well known statement that the free electron in vacuum cannot absorb photon. It follows from the special theory of relativity. Namely: if $p_1, p_2$ are the initial and final 4-momenta of electron with rest mass $m$ and $k$ is the 4-momentum of photon, then after absorption of photon by electron we write $k + p_1 = p_2$, which gives when squared $k^2 + 2kp_1 + p_1^2 = p_2^2$. Then, with $p_1^2 = p_2^2 = -m^2$ and $k^2 = 0$, we get for the rest electron with $\mathbf{p}_1 = 0$, the elementary relation $m\omega = 0$, Q.E.D..

The linear dependence on the frequency was experimentally determined in 1915, when Robert Andrews Millikan showed that Einstein formula

$$\hbar\omega = \frac{mv^2}{2} + W \tag{1}$$

was correct. Here $\hbar\omega$ is the energy of the impinging photon, $v$ is electron velocity measured by the magnetic spectrometer and $W$ is the work function of concrete material. The work function for Aluminium is 4.3 eV, for Beryllium 5.0 eV, for Lead 4.3 eV, for Iron 4.5 eV, and so on (Rohlf, 1994). More information on the work function is possible to find in the book by Lide (Lide, 2008). The work function concerns the surface photoelectric effect, where the photon is absorbed by an electron in a band. The theoretical determination of the work function is the problem of the solid state physics. On the other hand, there is the so called atomic photoeffect (Amusia, 1987), where the ionization energy plays the role of the work function. The system of the ionization energies is involved in the tables of the solid state physics. The work function is the one of the prestige problem of the contemporary experimental and theoretical crystal physics.

In case of the volume photoeffect, the ionization work function is defined in many textbooks on quantum mechanics. Or,

$$W = \int_{x_1}^{x_2} \left(\frac{dE}{dx}\right) dx \tag{2}$$

where $E$ is the energy loss of moving electron.

The formula (1) is the law of conservation of energy. The classical analogue of the equation (1) is the motion of the Robins ballistic pendulum in the resistive medium.

The Einstein ballistic principle is not valid inside of the blackbody. The Brownian motion of electrons in this cavity is caused by the repeating Compton process $\gamma + e \to \gamma + e$ and not by the ballistic collisions. The diffusion constant for electrons must be calculated from the Compton process and not from the ballistic process. The same is valid for electrons immersed into the cosmic relic photon sea.

The idea of the existence of the Compton effect is also involved in the Einstein article. He writes (Einstein, 1905; 1965): *The possibility should not be excluded, however, that electrons might receive their energy only in part from the light quantum.* However, Einstein was not sure, a priori, that his idea of such process is realistic. Only Compton proved the reality of the Einstein statement.

At energies $\hbar\omega < W$, the photoeffect is not realized. However, the photo-conductivity is the real process. The photoeffect is realized only in medium and with low energy photons, but with energies $\hbar\omega > W$, which gives the Compton effect negligible. Compton effect can be realized with electrons in medium and also with electrons in vacuum. For $\hbar\omega \gg W$ the photoeffect is negligible in comparison with the Compton effect. At the same time it is necessary to say that the Feynman diagram of the Compton effect cannot be reduced to the Feynman diagram for photoeffect. In case of the high energy gamma rays, it is possible to consider the process called photoproduction of elementary particles on protons in LHC, or photo-nuclear reactions in nuclear physics (Levinger, 1960). Such processes are energetically far from the photoelectric effect in solid state physics.

Eq. (1) represents so called one-photon photoelectric effect, which is valid for very weak electromagnetic waves. At present time of the laser physics, where the strong electromagnetic intensity is possible, we know that so called multiphoton photoelectric effect is possible. Then, instead of equation (1) we can write

$$\hbar\omega_1 + \hbar\omega_2 + ...\hbar\omega_n = \frac{mv^2}{2} + W. \tag{3}$$

The time lag between the incidence of radiation and the emission of a photoelectron is very small, less than $10^{-9}$ seconds.

As na analogue of the equation (3), the multiphoton Compton effect is also possible: $\gamma_1 + \gamma_2 + ...\gamma_n + e \rightarrow \gamma + e$ and two-electron, three-electron,... n-electron photoelectric effect is also possible (Amusia, 1987). To our knowledge the Compton process with the entangled photons was still not discovered and elaborated. On the other hand, there is the deep inelastic Compton effect in the high energy particle physics.

In *the second part* of the chapter we consider elementary explanation of the photoeffect ivolving the emission of phonon.

In the *third section* we consider the nonrelativistic quantum field theory of photoeffect in the form of ionization of atom involving the emission of phonon.

In the *4-th part*, we discuss the relativistic quantum field theory (QFT) of photoeffect in the form of ionization of atom involving the emission of phonon.

In the *5-th part* of the chapter we consider the polychromatic photoeffect to get the generalized Einstein formula (Pardy, 2009a).

The *6-th part* deals with photoelectric effect in the two-dimensional system in homogeneous magnetic field (Pardy, 2010).

The generalization of the photoeffect to the situation with the dressed photon is expressed in the *7-th part* of the chapter.

The *8-th part* deals with the H-atom immersed in the black-body photon sea. The situation is equivalent to the H-atom in the Gibbons-Hawking thermal bath and it is expected the important astrophysical meaning (Pardy, 2016a).

The *9-th part* consider the dielectric crystal immersed in the black-body which is equivalent to the influence of the index of refraction on the spectral formula of the black-body (Pardy, 2015a).

The thermal physics problem is also the situation of the Casimir effect at temperature $T$. The *10-th part* of the chapter deals with such situation (Pardy, 2016b).

The *11-th part* of the chapter is devoted to the Cherenkov radiation in the two-dimensional dielectric medium (Pardy, 2015b).

The *12-th part* of the chapter concerns the calculation of the velocity of sound in the relic photon sea which is the relic astrophysical black-body (Pardy, 2013a, 2013b).

The *13-th part* of the chapter is conclusion.

## 2 The photoelectric effect with the emission of phonon

A phonon is a collective excitation in a periodic, elastic arrangement of atoms, or, molecules in condensed matter, often designated a quasiparticle. It is an quantum mechanical excited state of the modes of vibrations of elastic structures of interacting particles. They play a major role in thermal conductivity and electrical conductivity. The concept of phonons was introduced in 1932 by Russian physicist Igor Tamm. The long-wavelength phonons give rise to sound. The higher-frequency phonons are responsible for the majority of the thermal capacity of solids.

Phonons have particle-like properties forming the wave particle duality known from quantum mechanics.

Acoustic phonons are coherent movements of atoms of the lattice out of their equilibrium positions similarly to the acoustic waves. They exhibit a linear relationship between frequency and phonon wave vector for long wavelengths. Optical phonons are out-of-phase movements of the atoms in the lattice, one atom moving to the left, and its neighbor to the right.

By analogy to photons and matter waves, phonon has wave vector $k$ and momentum $k$, however, $k$ is not actually a physical momentum; it is called pseudomomentum, because $k$ is only determined up to addition of constant vectors (the reciprocal lattice vectors and integer multiples thereof).

A phonon with wavenumber $k$ is thus equivalent to an infinite family of phonons with wavenumbers $k \pm 2\pi/a, k \pm 4\pi/a$, and so on, with $a$ being the lattice constant.

The thermodynamic properties of a solid are directly related to phonons. The phonon density of states determines the heat capacity of a crystal. Phonons generated by the temperature of the lattice are called thermal phonons.

The behavior of thermal phonons is similar to the photon gas in a cavity, wherein photons may be emitted or absorbed by the cavity walls. Einstein has considered such model to obtain the heat capacity and Debye performed the brilliant generalization of the Einstein model.

The impossibility of photon absorption by free electron can be demonstrated using the relativistic equations

$$\hbar\omega = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} \tag{1}$$

and

$$\frac{\hbar\omega}{c} = \frac{mv}{\sqrt{1-\frac{v^2}{c^2}}}, \tag{2}$$

where the second equation (2) is the expression of the conservation of momentum of the system pf particles photon and electron. After division of eq. (1) by eq. (2), ((1)/(2)), we get after elementary modification $1 = c/v$, which is logical contradiction.

Now, let us consider the situation, where electron is located in some medium where the Einstein work function is the necessary physical reality and the emission of phonon of the energy $\hbar\Omega$ is also the physical reality. Then instead of equations (1) and (2) we write

$$\hbar(\omega - \Omega) - W = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{3}$$

and

$$\frac{\hbar\omega}{c} = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}} + P = \frac{mv + P\sqrt{1 - \frac{v^2}{c^2}}}{\sqrt{1 - \frac{v^2}{c^2}}}, \tag{4}$$

where we have introduced $P$ as the momentum of phonon. After division of eq. (3) by eq. (4), ((3)/(4)), we get after elementary modification

$$\frac{\hbar(\omega - \Omega) - W}{\omega} = \frac{mc}{mv + P\sqrt{1 - \frac{v^2}{v^2}}}, \tag{5}$$

where there is no contradiction.

# 3 The QED photoelectric effect with phonon emission

The main idea of the quantum mechanical description of the photoeffect is the process of atom ionization. In case with the no phonon ejection it must be described by the appropriate S-matrix element involving the interaction of atom with the impinging photon with the simultaneous generation of the electron, the motion of which can be described approximately by the plane wave

$$\psi_{\mathbf{q}} = \frac{1}{\sqrt{V}} e^{i\mathbf{q}\cdot\mathbf{x}}, \quad \mathbf{q} = \frac{\mathbf{p}}{\hbar}, \tag{1}$$

where $\mathbf{p}$ is the momentum of the ejected electron.

The standard approach consists in the definition of the cross-section by the quantum mechanical equation (Berestetzky et al., 1989):

$$d\sigma = \frac{2\pi}{\hbar}|V_{fi}|\delta(-I + \hbar\omega - \varepsilon)\frac{d^3p}{(2\pi)^3}, \tag{2}$$

where $I$ is the ionization energy of an atom and $\varepsilon = E_f$ is the the final energy of the emitted electron, $|V_{fi}|$ is the matrix element of the transition of electron from the initial bound state to the final state. The matrix element follows from the perturbation theory and it involves the first order term of the interaction between electron and photon.

In case that the electro-process is accompanied by the phonon emission with the energy $E = \hbar\Omega$, the last formula is presented with very small modification, leading however to the interesting experimental result.

$$d\sigma = \frac{2\pi}{\hbar}|V_{fi}|\delta(-I + \hbar\omega - \hbar\Omega - \varepsilon)\frac{d^3p}{(2\pi)^3}. \tag{3}$$

We suppose in a sufficient distance from atom the wave function is of the form of the plane wave (1) which is the classical atomic situation discussed in monograph (Davydov, 1976). However, if the photon energy only just exceeds the ionization energy $I$ of atom, then we cannot used the plane wave approximation but the wave function of the continuous spectrum.

The probability of the emission of electron by the electromagnetic wave is of the well-known form (Berestetzky et al., 1989) (we use nomenclature with $\hbar = 1$):

$$V_{fi} = -e\mathbf{A}\mathbf{j} = -e\sqrt{4\pi}\frac{1}{\sqrt{2\omega}}M_{fi}, \tag{4}$$

where

$$M_{fi} = \int \psi'^{*}(\boldsymbol{\alpha}\mathbf{e})e^{i\mathbf{k}\cdot\mathbf{r}}\psi d^3x \tag{5}$$

where $\psi = \psi_i, \psi' = \psi_f$ is the initial and final wave function of electron (Berestetzky et al. 1989).

Using (Berestetzky et al., 1989)

$$d^3p = \mathbf{p}^2 d|\mathbf{p}|do = \varepsilon|\mathbf{p}|d\varepsilon do, \tag{6}$$

we get after integration of the $\delta$-function over $\varepsilon$

$$d\sigma = e^2\frac{\varepsilon|\mathbf{p}|}{2\pi\omega}|M_{fi}|^2. \tag{7}$$

Let us consider the case with $I \ll \omega \ll m$. It follows from $\omega \ll m$ that the velocity of electron is very small and it means that matrices $\boldsymbol{\alpha}_k$ can be replaced by the operators (Berestetzky et al., 1989 § 45)

$$\boldsymbol{\alpha}_k \to -i\nabla_k/m. \tag{8}$$

At the same time we use the dipole approximation with $\exp(i\mathbf{kr}) \approx 1$. Then we get

$$d\sigma = e^2\frac{\varepsilon|\mathbf{p}|}{2\pi\omega}|\mathbf{e}\mathbf{v}_{fi}|^2 do, \tag{9}$$

where,

$$\mathbf{v}_{fi} = -\frac{i}{m}\int \psi'^{*}\nabla\psi d^3x. \tag{10}$$

Let us consider the photoeffect from the basic level of atom, then $\psi = \psi_i$, or

$$\psi = \frac{(Ze^2m)^{3/2}}{\sqrt{\pi}}e^{-Ze^2mr}. \tag{11}$$

(In the standard units $me^2 \to 1/a_0$ with $a_0 = \hbar^2/me^2$, $a_0$ being the Bohr radius). Function $\psi'$ is taken in such a way that its asymptotic form is the exponential form (1) and together with this form it involves the convergent spherical wave $\psi^-_{\mathbf{p}}$. According to (Landau et al., 1991, § 36) we write

$$\psi^-_{\mathbf{p}} = \frac{1}{p}\sum_{l=0}^{l=\infty} i^l(2l+1)a^{-i\delta_l}R_{pl}(r)P_l(\mathbf{n}\mathbf{n}_1), \tag{12}$$

where $\mathbf{n} = \mathbf{p}/p, \mathbf{n_l} = \mathbf{r}/r, p = |\mathbf{p}|$, and $\psi'$ describes the transition from the s-state to the p-state according to the selection rule (the dipole case), which means that it is possible to put $l = 1$ (Landau et al., 1991, § 36).

Ignoring the nonsubstantional coefficients, we write

$$\psi' = \frac{3}{2p}(\mathbf{n}\mathbf{n}_1)R_{p1}(r). \tag{13}$$

We get with function from (11) and (13) the following expression

$$\mathbf{e}\mathbf{v}_{fi} = \frac{3(Ze^2m)^{5/2}}{2\sqrt{\pi}mp}\int\int(\mathbf{n}\mathbf{n}_1)(\mathbf{n}_1\mathbf{e})e^{-Ze^2mr}R_{p1}(r)do_1r^2dr =$$

$$\frac{\sqrt{2\pi}(Ze^2m)^{5/2}}{pm}(\mathbf{ne})\int_0^\infty r^2e^{-Ze^2mr}R_{p1}(r)dr. \tag{14}$$

We get with (Landau et al., 1991, § 36, eq. 36.18) and (Landau et al., 1991, § 36, eq. 36.24) for $R_{p1}$:

$$R_{p1} = \frac{\sqrt{8\pi 2e^2m}}{3}\sqrt{\frac{1+\nu^2}{\nu(1-e^{-2\pi\nu})}}pr.e^{-ipr}F(2+i\nu,4,2ipr) \tag{15}$$

with

$$\nu = \frac{2e^2m}{p} = \frac{Ze^2}{\hbar v}. \tag{16}$$

Now, it is necessary to calculate the integral in (14). To realize the goal, we use the following identity:

$$\int_0^\infty e^{-\lambda z}z^{\gamma-1}F(\alpha,\gamma,kz) = \Gamma(\gamma)\lambda^{\alpha-\gamma}(\lambda-k)^{-\alpha}. \tag{17}$$

Using the elementary relation

$$\left(\frac{\nu+i}{\nu-i}\right)^{i\nu} = e^{-2\nu\arctan\nu} \tag{18}$$

we get

$$\mathbf{e}\mathbf{v}_{ij} = \frac{2^{7/2}\pi\nu^3(\mathbf{ne})}{\sqrt{p}m(1+\nu^2)^{3/2}}\frac{e^{-2\nu\arctan\nu}}{\sqrt{1-e^{-2\pi\nu}}}. \tag{19}$$

The $\delta$-function function involves the conservation law in the form

$$\omega = \frac{p^2}{2m} + I = \frac{p^2}{2m}(1+\nu^2). \tag{20}$$

Using the last equation, we get

$$d\sigma = 2^7\pi\alpha a^2\left(\frac{I}{\hbar\omega}\right)^4(\mathbf{ne})^2\frac{e^{-4\nu\arctan\nu}}{1-e^{-2\pi\nu}}do, \tag{21}$$

where

$$a = \frac{\hbar^2}{mZe^2} = a_0/Z. \tag{22}$$

In case of the nonpolarized photon, $d\sigma$ must be averaged in $\mathbf{e}$, which leads to transition (Berestetzky et al., 1989; § 45, eq. 45. 4b):

$$(\mathbf{ne})^2 = \frac{1}{2}(\mathbf{n}_0 \times \mathbf{e})^2; \quad \mathbf{n}_0 = \mathbf{k}/k. \tag{23}$$

After integration over all angles in $d\sigma$, we get the Stobbe formula (Stobbe, 1930)

$$\sigma = (2^9/3)\pi^2\alpha a^2 \left(\frac{I}{\hbar\omega}\right)^4 \frac{e^{-4\nu \arctan \nu}}{1 - e^{-2\pi\nu}}. \tag{24}$$

In case $\hbar\omega \gg I$ and at the same time $\hbar\omega \ll mc^2$ we get

$$\sigma = (2^8/3)\pi\alpha a_0^2 Z^5 \left(\frac{I_0}{\hbar\omega}\right)^{7/2}; \quad I_0 = \frac{e^4 m}{2\hbar^2}. \tag{25}$$

Now, let as consider the QED photoelectric effect with phonon emission with the the conservation law

$$\hbar\omega = \varepsilon + I + \hbar\Omega, \tag{26}$$

which can be physically interpreted in such a way as the photoelectric effect with the initial energy $\hbar\omega - \hbar\Omega$. It mathematically means that the final formulas for the photoeffect (24) and (25) must be modified by the relation $\omega \to \omega - \Omega$, or,

$$\sigma = (2^9/3)\pi^2\alpha a^2 \left(\frac{I}{\hbar\omega - \hbar\Omega}\right)^4 \frac{e^{-4\nu \arctan \nu}}{1 - e^{-2\pi\nu}}. \tag{27}$$

In case $\hbar\omega \gg I$ and at the same time $\hbar\omega \ll mc^2$ we get

$$\sigma = (2^8/3)\pi\alpha a_0^2 Z^5 \left(\frac{I_0}{\hbar\omega - \hbar\Omega}\right)^{7/2}; \quad I_0 = \frac{e^4 m}{2\hbar^2}. \tag{28}$$

The last formula can be experimentally verified in the analogue with the Einstein formula.

# 4 The relativistic QED photoelectric effect with phonon emission

Let us consider the case with

$$\omega \gg I. \tag{1}$$

In this case $\varepsilon = \omega - I \gg I$ and then the influence of Coulomb field of nucleus on the wave function of the photoelectron $\psi'$ can be determined by the theory of perturbation. So we write (Berestetzky et al., 1989):

$$\psi' = \frac{1}{\sqrt{2\varepsilon}}(u' e^{i\mathbf{pr}} + \psi^{(1)}). \tag{2}$$

The relativistic motion of the electron is involved in the plane wave of electron in formula (2).

The function $\psi$ is take according to § 39 in the form:

$$\psi = \left(1 - \frac{i}{2m}\gamma^0 \boldsymbol{\gamma}\nabla\right) \frac{u}{\sqrt{2m}}\psi_{nonrel}, \tag{3}$$

where $\psi_{nonrel}$ is the nonrelativistic function of the bound state (11) sect. 3 , and $u$ is the bispinor amplitude of the rest electron with the normalization $\bar{u}u = 2m$.

Now, let us insert functions $\psi, \psi'$ into the matrix element

$$M_{fi} = \int \psi'^{*}(\boldsymbol{\alpha}\mathbf{e})e^{i\mathbf{k}\cdot\mathbf{r}}\psi dx^3. \tag{4}$$

Then, we get

$$M_{fi} = \frac{1}{2\sqrt{m\varepsilon}}\times$$

$$\int \left\{\bar{u}'(\boldsymbol{\gamma}\mathbf{e})\left[\left(1 - \frac{i}{2m}\gamma^0\boldsymbol{\gamma}\nabla\right) u\psi_{nonrel}\right] e^{-i(\mathbf{p}-\mathbf{k})\mathbf{r}} + \bar{\psi}^{(1)}(\boldsymbol{\gamma}\mathbf{e})e^{i\mathbf{kr}}u\psi_{nonrel}\right\} d^3x. \tag{5}$$

Now, we approximate the wave function in [..] by constant as follows (Berestetzky et al., 1989):

$$\psi_{nonrel} = \frac{(Ze^2m)^{3/2}}{\sqrt{\pi}}. \tag{6}$$

Then, after integration by per partes of the first term in eq. (5) in order to get the exponential term, we get

$$M_{fi} = \frac{(Ze^2m)^{3/2}}{2\sqrt{\pi m\varepsilon}}\left\{\bar{u}'(\boldsymbol{\gamma}\mathbf{e})\left[1 + \frac{1}{2m}\gamma^0\boldsymbol{\gamma}(\mathbf{p}-\mathbf{k}\right]\left(e^{-Ze^2mr}\right)_{\mathbf{p}-\mathbf{k}} + \bar{\psi}^{(1)}_{-\mathbf{k}}(\boldsymbol{\gamma}\mathbf{e})u\right\}, \tag{7}$$

where the vector component is as follows in approximation in term $Ze^2$:

$$\left(e^{-Ze^2mr}\right)_{\mathbf{p}-\mathbf{k}} = \frac{8\pi Ze^2m}{(\mathbf{p}-\mathbf{k})^4}. \tag{8}$$

After insertion of $\psi'$ from eq. (2) into the Dirac equation

$$[\gamma(p - eA) - m]\psi = 0 \tag{9}$$

we get the following equation for $\psi^{(1)}$:

$$\left(\gamma^0\varepsilon + i\gamma^0\boldsymbol{\gamma}\nabla - m\right)\psi^{(1)} = e(\gamma^\mu A_\mu)u'e^{i\mathbf{pr}} = -\frac{(Ze^2}{r}\gamma^0u'e^{i\mathbf{pr}}. \tag{10}$$

After application of the operator

$$\left(\gamma^0\varepsilon + i\gamma^0\boldsymbol{\gamma}\nabla + m\right) \tag{11}$$

to the last equation, we get

$$(\Delta+\mathbf{p}^2)\psi^{(1)}_{\mathbf{k}} = -Ze^2\left(\gamma^0\varepsilon + i\boldsymbol{\gamma}\nabla + m\right)(\gamma^0 u')\frac{1}{r}e^{i\mathbf{pr}}. \tag{12}$$

Now, let us multiply the last equation by $e^{-i\mathbf{kr}}$ and perform the integration in $d^3x$. We perform the integration per partes in terms with $\Delta$ and $\nabla$. We get:

$$(\mathbf{p}^2+\mathbf{k}^2)\psi^{(1)}_{\mathbf{k}} = -Ze^2\left(\gamma^0\varepsilon - \boldsymbol{\gamma}\mathbf{k} + m\right)(\gamma^0 u')\left(\frac{1}{r}\right)_{\mathbf{k}-\mathbf{p}} =$$

$$-Ze^2\left(2\gamma^0\varepsilon - \boldsymbol{\gamma}(\mathbf{k}-\mathbf{p}) + m\right)(\gamma^0 u')\left(\frac{4\pi}{(\mathbf{k}-\mathbf{p})^2}\right). \tag{13}$$

We used the following equations

$$\left(\gamma^0\varepsilon - \mathbf{p}\boldsymbol{\gamma} - m\right)u' = 0; \quad \left(\gamma^0\varepsilon + \mathbf{p}\boldsymbol{\gamma} - m\right)\gamma^0 u' = 0 \tag{14}$$

in the last line of eq. (13)
So, we get:

$$\bar{\psi}^{(1)}_{-\mathbf{k}} = \psi^{(1)*}_{\mathbf{k}}\gamma^0 = 4\pi Ze^2\bar{u}'\frac{2\gamma^0\varepsilon + \boldsymbol{\gamma}(\mathbf{k}-\mathbf{p})}{(\mathbf{k}^2-\mathbf{p}^2)(\mathbf{k}-\mathbf{p})^2}\gamma^0. \tag{15}$$

After insertion of eqs. (8) and (15) into matrix element (7), we get

$$M_{fi} = \frac{4\pi^{1/2}(Ze^2m)^{5/2}}{(\varepsilon m)^{1/2}(\mathbf{k}-\mathbf{p})^2}\bar{u}'Au, \tag{16}$$

where

$$A = a(\boldsymbol{\gamma}\mathbf{e}) + (\boldsymbol{\gamma}\mathbf{e})\gamma^0(\boldsymbol{\gamma}\mathbf{b}) + (\boldsymbol{\gamma}\mathbf{c})\gamma^0\boldsymbol{\gamma}\mathbf{e} \tag{17}$$

with

$$a = \frac{1}{(\mathbf{k}-\mathbf{p})^2} + \frac{\varepsilon}{m}\frac{1}{(\mathbf{k}^2-\mathbf{p}^2)}, \quad \mathbf{b} = -\frac{\mathbf{k}-\mathbf{p}}{2m(\mathbf{k}-\mathbf{p})^2}, \quad \mathbf{c} = \frac{\mathbf{k}-\mathbf{p}}{2m(\mathbf{k}^2-\mathbf{p}^2)}. \tag{18}$$

Now, the cross-section is of the form:

$$d\sigma = \frac{8e^2(Ze^2m)^5|\mathbf{p}|}{\omega m(\mathbf{k}-\mathbf{p})^4}(\bar{u}'Au)(\bar{u}\bar{A}u')do, \tag{19}$$

where $\bar{A} = \gamma^0 A^+\gamma^0$. The derived cross-section must be summed through the final direction of spins and averaged through the final spin directions. Such operations can be easily performed using the polarization matrices of the initial and final states as follows:

$$\varrho = \frac{m}{2}(\gamma^0+1), \quad \varrho' = \frac{m}{2}(\gamma^0\varepsilon - \boldsymbol{\gamma}\mathbf{p} + m). \tag{20}$$

Let us remark that in the initial state is $\mathbf{p} = 0, \varepsilon = m$. Using eq. (20), we get the cross-section is the form:

$$d\sigma = \frac{16e^2(Ze^2m)^5|\mathbf{p}|}{\omega m(\mathbf{k}-\mathbf{p})^4}\mathrm{Sp}(\varrho' A\varrho\bar{A})do, \tag{21}$$

The spur of the mathematical object is according to Berestetzky et al. (1989) as follows:

$$\mathrm{Sp}(\varrho' A \varrho \bar{A}) =$$

$$\frac{m}{\varepsilon + m}[a\mathbf{p} - (\mathbf{b} - \mathbf{c})(\varepsilon + m)]^2 + 4m(\mathbf{be})[(\varepsilon + m)a(\mathbf{ce}) + a(\mathbf{pe})], \tag{22}$$

where vector $\mathbf{e}$ is real for the linear polarization.

Now, let us introduce the polar angle $\varphi$, azimut angle $\theta$ of the direction $\mathbf{p}$ with regard to $\mathbf{k}$ as the $z$-axis is the plane $\mathbf{k}, \mathbf{e}$ forming the $xz$ plain (which means that $\mathbf{pe}$) $|\mathbf{p}| = \cos\varphi \sin\theta$. For $\omega \gg I$ there is the conservation energy in the form $\varepsilon - m = \omega$.

It may be easy to see that

$$(\mathbf{k}^2 - \mathbf{p}^2) = -2m(\varepsilon - m), \quad (\mathbf{k} - \mathbf{p})^2 = 2\varepsilon(\varepsilon - m)(1 - v\cos\theta), \tag{23}$$

where $\mathbf{vp}/\varepsilon$ is the velocity of photon. After some mathematical operation we get the final form of the differential cross-section:

$$d\sigma = Z^5\alpha^4 r_e^2 \frac{v^3(1 - v^2)^3 \sin^2\theta}{(1 - \sqrt{1 - v^2})^5(1 - v\cos\theta)^4} \quad \times$$

$$\left\{ \frac{(1 - \sqrt{1 - v^2})^2(1 - v\cos\theta)}{2(1 - v^2)^{3/2}} \quad + \right.$$

$$\left. \left[ 2 - \frac{(1 - \sqrt{1 - v^2})(1 - v\cos\theta)}{(1 - v^2)} \right] \cos^2\varphi \right\} do, \tag{24}$$

where $r_e = e^2/m$.

It is $\varepsilon \gg m$ for the ultrarelativistic situation and the photoeffect has the sharp maximum for small angles $\theta \sim (1 - v^2)^{1/2}$, which means that electrons are emitted maximally in the direction of motion of photon.

We have in the vicinity of maximum:

$$1 - v\cos\theta \approx \frac{1}{2}[(1 - v^2) + \theta^2] \tag{25}$$

Then, the main terms in eq. (24) gives

$$d\sigma \approx 4Z^5\alpha^4 r_e^2 \frac{(1 - v^2)^{3/2} + \theta^3}{(1 - v^2 + \theta^2)^3} d\theta d\varphi \tag{26}$$

After elementary but long integration of eq. (26) we get the total differential cross-section of the photoelectric effect (Sauter, 1931; Berestetzky et al., 1989):

$$d\sigma = 4\pi Z^5\alpha^4 r_e^2 \frac{(\gamma^2 - 1)^{3/2}}{(\gamma - 1)^5} \quad \times$$

$$\left\{ \frac{4}{3} + \frac{\gamma(\gamma - 2)}{\gamma + 1} \left( 1 - \frac{1}{2\gamma\sqrt{\gamma^2 - 1}} \ln \frac{\gamma + (\gamma^2 - 1)^{1/2}}{\gamma - (\gamma^2 - 1)^{1/2}} \right) \right\}, \tag{27}$$

where we introduced the Lorentz factor

$$\gamma = (1 - v^2)^{-1/2} = \frac{\varepsilon}{m} \approx \frac{m + \omega}{m}. \tag{28}$$

In case of the ultrarelativistic situation, we get the most simple expression

$$d\sigma = 2\pi Z^5 \alpha^4 r_e^2 / \gamma. \tag{29}$$

In case $I \ll \omega \ll m$, we have in the limiting case for small $\gamma - 1$, the known result (25), in section 3.

# 5 The polychromatic photoelectric effect

The physical meaning of the Einstein equation (1) (sect. 1) is in the interaction of the monochromatic photon beam with energy $\hbar\omega$ with an electron in matter. The possible generalization of the Einstein equation is, to consider the situation where the metal film absorbs the photons with the Planckian energy distribution of photons of the blackbody:

$$\varrho(\omega) = \frac{\omega^2}{\pi^2 c^3} \frac{\hbar\omega}{e^{\frac{\hbar\omega}{kT}} - 1}, \tag{1}$$

or, the synchrotron radiation with the photon density (Jackson, 1999) (in the asymptotic limit case)

$$P(\omega) = \frac{I}{\hbar\omega_c} \frac{9\sqrt{3}}{8\pi} \int_y^\infty K_{5/3} x) dx; \qquad y = \frac{\omega}{\omega_c};\ \omega_c = \frac{3}{2}\left(\frac{E}{mc^2}\right)^3 \frac{c}{R} \tag{2}$$

with

$$I = \frac{4\pi^2 e^2 \gamma^4}{3R};\ \gamma = \frac{1}{\sqrt{1 - v^2/c^2}}, \tag{3}$$

where $R$ is the radius of the curvature, $v$ is the relativistic velocity of an electron moving along curved trajectory and $K_{5/3}$ is the modified McDonald function of the index 5/3.

In the first case with the blackbody situation, we multiply the Einstein original equation by the density of photons

$$n(\omega) = \frac{\omega^2}{\pi^2 c^3} \frac{1}{e^{\frac{\hbar\omega}{kT}} - 1} \tag{4}$$

and integrate from the threshold frequency $\omega_0 = W/\hbar$ to infinity to get the polychromatic photoelectric equation:

$$\int_{\omega_0}^\infty n(\omega)\hbar\omega d\omega = \int_{\omega_0}^\infty n(\omega) d\omega \frac{mv^2}{2} + W \int_{\omega_0}^\infty n(\omega) d\omega. \tag{5}$$

The last equation is the generalization of the original Einstein equation from 1905 to the situation that matter is irradiated by the photons from the blackbody cavity.

In case that the matter is irradiated by the laser field with the known spectral distribution, the the symbol $n(\omega)$ in the last equation is of the physical meaning of the spectral distribution of photons in the laser beam.

Function

$$\int_{\omega_0}^{\infty} n(\omega) d\omega \frac{mv^2}{2} = E_{kin} \tag{6}$$

has the physical meaning of the total energy of the emitted electrons of different velocities during the photoeffect and it can be determined by the adequate experimental technique.

Function

$$\int_{\omega_0}^{\infty} n(\omega) d\omega = N(W, T) \tag{7}$$

is the total number of photons emitted by the blackbody in the interval $(\omega_0, \infty)$. It depends on the work function W an on the temperature of the thermal bath which is in our case the blackbody.

We can write the polychromatic photoelectric equation in the following form:

$$\int_0^{\infty} n(\omega)\hbar\omega d\omega - \int_0^{\omega_0} n(\omega)\hbar\omega d\omega = E_{kin} + WN(W, T), \tag{8}$$

or, in the modified form

$$aT^4 - \int_0^{\omega_0} n(\omega)\hbar\omega d\omega = E_{kin} + WN(W, T), \tag{9}$$

where the term $aT^4$ was obtained by the obligate mathematical procedure

$$\int_0^{\infty} \varrho(\omega) d\omega = \int_0^{\infty} n(\omega)\hbar\omega d\omega = \int_0^{\infty} \frac{\omega^2}{\pi^2 c^3} \frac{\hbar\omega}{e^{\frac{\hbar\omega}{kT}} - 1} d\omega = \frac{\pi^2}{15} \frac{k^4 T^4}{c^3 \hbar^3} = aT^4. \tag{10}$$

We know from the textbooks that

$$a = \frac{\pi^2 k^4}{15 c^3 \hbar^3} = 7.56 \times 10^{-13} \text{erg.cm}^{-3}.\text{grad}^{-4}. \tag{11}$$

The equation (9) is of the two scientific meaning. The first meaning is the mathematical. Namely, if we obtain from the experiment the quantity $E_{kin}$, then the equation (9) is the mathematical equation for the determination of the work function W, where, however the work function W is also inbuilt in the integral. In other words, it is the new and original mathematical problem of elimination of some quantity from the nontrivial equation.

The next physical meaning of the equation (9) is, that the work function W is defined by the quantum collective motion of electrons and we know that the quantum collective motion of electrons is not the sum of the individual motion of electrons along the individual trajectories. So, the work function obtained from the polychromatic photoelectric equation (9) differs from the work function obtained from the monochromatic Einstein equation (1). The theoretical determination of the two different work functions represents the basic, the fundamental and the crucial problem of the quantum theory of the solid state physics and this problem was not till this time solved.

The same procedure can be performed using the distribution function of photons of the synchrotron radiation, where instead the blackbody density of photons is the synchrotron density of photons $P(\omega)$.

$$\int_{\omega_0}^{\infty} P(\omega)\hbar\omega d\omega = E_{kin} + WN_{synchro}. \quad (12)$$

We can easily determine the work function only by the measurement of the total energy of the emitted electron during the photoeffect.

Let us remark, that the main motivation of the Einstein approach was the solid state proof of the existence of the light quanta. The possible next step was the generalization of the photoelectric effect for the situation where the absorption of photons is polychromatic, generated for instance by the blackbody, or by the synchrotron. In time of the Einstein photoelectric derivation, the blackbody radiation was under discussion and the Schott formula for the synchrotron radiation was not derived. So, the Einstein motivation to go beyond his photoelectric equation was not sufficiently strong. Now, the polychromatic form of the Einstein photoelectric equation is physically meaningful.

It is not excluded, a priori, that the collective motion of electrons in multiphoton experiment influences the work function in such a way that it is different from the work function in case where we use only the monochromatic light generating the individual motion of electrons. The measurement and investigation of eqs. (9), (12) can be considered as crucial and leading to the new discoveries in the photonic physics, elementary particle physics and solid state physics.

The information following from the polychromatic photoelectric effect is necessary not only in the solid state physics, but also in the elementary particle physics where multiphoton beams play the substantial role of the particle detectors.

# 6 The photoelectric effect in the 2D electron gas in strong magnetic field

The S-matrix element involving the interaction of an atom with the impinging photon and with the ejected electron with the final plane wave

$$\psi_{\mathbf{q}} = \frac{1}{\sqrt{V}} e^{i\mathbf{q}\cdot\mathbf{x}}, \quad \mathbf{q} = \frac{\mathbf{p}}{\hbar}, \quad (1)$$

where $\mathbf{p}$ is the momentum of the ejected electron, gives the quantum mechanical cross-section

$$d\sigma = \frac{2\pi}{\hbar}|V_{fi}|\delta(-I + \hbar\omega - E_f)\frac{d^3p}{(2\pi)^3}, \quad (2)$$

where $I$ is the ionization energy of an atom and $E_f$ is the the final energy of the emitted electron, $|V_{fi}|$ is the matrix element of the transition of electron from the initial bound state to the final state. The matrix element foollows from the perturbation theory and it involves the first order term of the interaction between electron and photon. We follow here the Davydov elementary approach (Davydov, 1976).

We suppose here that magnetic field is applied locally to 2D sheet of electrons , so, in a sufficient distance from it the wave function is of the form of the plane wave (1). Let us remark that if the photon energy only just exceeds the ionization energy $I$ of atom, then we cannot used the plane wave approximation but the wave function of the continuous spectrum.

The probability of the emission of electron by the electromagnetic wave is of the well-known form (Davydov, 1976):

$$dP = \frac{e^2 p}{8\pi^2 \varepsilon_0 \hbar m\omega}\left|\int e^{i(\mathbf{k}-\mathbf{q})\cdot\mathbf{x}}(\mathbf{e}\cdot\nabla)\psi_0 dxdydz\right|^2 d\Omega = C|J|^2 d\Omega, \tag{3}$$

where the interaction for absorption of the electromagnetic wave is normalized to *one photon in the unit volume*, $\mathbf{e}$ is the polarization of the impinging photon, $\varepsilon_0$ is the dielectric constant of vacuum, $\psi_0$ is the basic state of and atom. We have denoted the integral in $||$ by $J$ and the constant before $||$ by C.

We consider the case with electrons in magnetic field as an analog of the Landau diamagnetism. So, we take the basic function $\psi_0$ for one electron in the lowest Landau level, as

$$\psi_0 = \left(\frac{m\omega_c}{2\pi\hbar}\right)^{1/2} \exp\left(-\frac{m\omega_c}{4\hbar}(x^2+y^2)\right), \tag{4}$$

which is solution of the Schrödinger equation in the magnetic field with potentials $\mathbf{A} = (-Hy/2, -Hx/2, 0, 0)$, (Drukarev, 1988):

$$\left[\frac{p_x^2}{2m} + \frac{p_y^2}{2m} - \frac{m}{2}\left(\frac{\omega_c}{2}\right)^2 (x^2+y^2)\right]\psi = E\psi. \tag{5}$$

We have supposed that the motion in the z-direction is zero and it means that the wave function $\exp[(i/\hbar)p_z z] = 1$.

So, the main problem is to calculate the integral

$$J = \int e^{i(\mathbf{K}\cdot\mathbf{x})}(\mathbf{e}\cdot\nabla)\psi_0 dxdydz; \quad \mathbf{K} = \mathbf{k} - \mathbf{q}. \tag{6}$$

with the basic Landau function $\psi_0$ given by the equation (4).

Operator $(\hbar/i)\nabla$ is Hermitean and it means we can rewrite the last integrals as follows:

$$J = \frac{i}{\hbar}\mathbf{e}\cdot\int\left[\left(\frac{\hbar}{i}\nabla\right)e^{i(\mathbf{K}\cdot\mathbf{x})}\right]^* \psi_0 dxdydz, \tag{7}$$

which gives

$$J = i\mathbf{e}\cdot\mathbf{K}\int e^{-i(\mathbf{K}\cdot\mathbf{x})}\psi_0 dxdydz, \tag{8}$$

The integral in eq. (8) can be transformed using the cylindrical coordinates with

$$dxdydz = \varrho d\varrho d\varphi dz, \quad \varrho^2 = x^2 + y^2 \tag{9}$$

which gives for vector $\mathbf{K}$ fixed on the axis z with $\mathbf{K}\cdot\mathbf{x} = Kz$ and with physical condition $\mathbf{e}\cdot\mathbf{k} = 0$, expressing the physical situation where polarization is perpendicular to the direction of the wave propagation. So,

$$J = (i)(\mathbf{e}\cdot\mathbf{q})\int_0^\infty \varrho d\varrho \int_{-\infty}^\infty dz \int_0^{2\pi} d\varphi e^{-iKz}\psi_0. \tag{10}$$

Using

$$\psi_0 = A\exp\left(-B\varrho^2\right); \quad A = \left(\frac{m\omega_c}{2\pi\hbar}\right)^{1/2}; \quad B = \frac{m\omega_c}{4\hbar}. \tag{11}$$

The integral (12) is then

$$J = (-\pi i)\frac{A}{B}(\mathbf{e}\cdot\mathbf{q})\int_{-\infty}^{\infty} e^{-iKz}dz = (-\pi i)\frac{A}{B}(\mathbf{e}\cdot\mathbf{q})(2\pi)\delta(K). \tag{12}$$

Then,

$$dP = C|J|^2 d\Omega = 4\pi^4\frac{A^2}{B^2}C(\mathbf{e}\cdot\mathbf{q})^2\delta^2(K)d\Omega. \tag{13}$$

Now, let be the angle $\Theta$ between direction $\mathbf{k}$ and direction $\mathbf{q}$, and let be the angle $\Phi$ between planes $(\mathbf{k},\mathbf{q})$ and $(\mathbf{e},\mathbf{k})$. Then,

$$(\mathbf{e}\cdot\mathbf{q})^2 = q^2\sin^2\Theta\cos^2\Phi. \tag{14}$$

So, the differential probability of the emission of photons from the graphene (Pardy, 2010) in the strong magnetic field is as follows:

$$dP = \frac{4e^2p}{\pi\varepsilon_0 m^2\omega\omega_c}\left[q^2\cos^2\Theta\sin^2\Phi\right]\delta^2(K)d\Omega; \quad \omega_c = \frac{|e|H}{mc}. \tag{15}$$

We can see that our result differs form the result for the original photoelectric effect which involves still the term

$$\frac{1}{(1-\frac{v}{c}\cos\Theta)^4}, \tag{16}$$

which means that the most intensity of the classical photoeffect is in the direction of the electric vector of the electromagnetic wave $(\Phi = \pi/2, \Theta = 0)$. While the nonrelativistic solution of the photoeffect in case of the Coulomb potential was performed by Stobbe (1930) and the relativistic calculation by Sauter (Sauter, 1931), the general magnetic photoeffect (with electrons moving in the magnetic field and forming atom) was not still performed in a such simple form. The delta term $\delta\cdot\delta$ represents the conservation law $|\mathbf{k}-\mathbf{q}| = 0$ in our approximation.

So, we have calculated only the process which can be approximated by the Schrödinger equation for an electron orbiting in magnetic field.

## 6.1 The photoelectric effect with Volkov solution

It is valuable from the pedagogical point of view (Berestetzky et al., 1989) to remember the Volkov solution, where the motion of the Dirac electron is considered in the following four potential

$$A_\mu = a_\mu\varphi; \quad \varphi = kx; \quad k^2 = 0. \tag{17}$$

From equation (23), it follows that $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu = a_\nu k_\mu - a_\mu k_\nu = const.$, which means that electron moves in the constant electromagnetic field with the components $\mathbf{E}$ and $\mathbf{H}$. The parameters $a$ and $k$ can be chosen in a such a way that $\mathbf{E} = 0$. So, the motion of electron is performed in the constant magnetic field.

The Volkov (1935) solution of the Dirac equation for an electron moving in a field of a plane wave was derived in the form (Berestetzky et al., 1989; Pardy, 2004):

$$\psi_p = \frac{u(p)}{\sqrt{2p_0}}\left[1 + e\frac{(\gamma k)(\gamma A(\varphi))}{2kp}\right]\exp\left[(i/\hbar)S\right] \tag{18}$$

and $S$ is an classical action of an electron moving in the potential $A(\varphi)$ (Berestetzky et al., 1989).

$$S = -px - \int_0^{kx} \frac{e}{(kp)}\left[(pA) - \frac{e}{2}(A)^2\right] d\varphi. \tag{19}$$

It was shown that for the potential (17) the Volkov wave function is (Berestetzky et al., 1989):

$$\psi_p = \frac{u(p)}{\sqrt{2p_0}}\left[1 + e\frac{(\gamma k)(\gamma a)}{2kp}\varphi\right]\exp\left[(i/\hbar)S\right] \tag{20}$$

with

$$S = -e\frac{ap}{2kp}\varphi^2 + e^2\frac{a^2}{6kp}\varphi^3 - px. \tag{21}$$

We used $c = \hbar = 1$.

However, the relativistic wave function can be obtained by solving the Dirac equation in magnetic field. It was derived in the form (Sokolov et al., 1983).

$$\Psi(\mathbf{x}, t) = \frac{1}{L}\exp\{-\frac{i}{\hbar}\epsilon Et + ik_2y + ik_3z\}\psi; \quad \psi = \begin{pmatrix} C_1u_{n-1}(\eta) \\ iC_2u_n(\eta) \\ C_3u_{n-1}(\eta) \\ iC_4u_n(\eta) \end{pmatrix}, \tag{22}$$

where $\epsilon = \pm 1$ and the spinor components are given by the following formulas:

$$u_n(\eta) = \sqrt{\frac{\sqrt{2\gamma}}{2^n n!}\sqrt{\pi}}\, e^{-\eta^2/2}H_n(\eta) \tag{23}$$

with

$$H_n(\eta) = (-1)^n e^{\eta^2}\left(\frac{d}{d\eta}\right)^n e^{-\eta^2}, \tag{24}$$

$$\eta = \sqrt{2\gamma}\, x + k_2/\sqrt{2\gamma}; \quad \gamma = eH/2c\hbar. \tag{25}$$

The coefficients $C_i$ are defined in the Sokolov et al. monograph (Sokolov et al., 1983). So, our approach can be generalized.

# 7 The photoeffect with the dressed photon

We define here the dressed photon as a such with the additional radiative corrections, where we take the radiative correction in the form of the virtual electron-positron pair. We have shown that such approach to the photon leads to the modification he photon propagator. According to Dittrich (1978) and Schwinger (1973), the photon propagator with radiative correction is in the momentum representation of the form:

$$\tilde{D}(k) = D(k) + \delta D(k), \tag{1}$$

or,

$$\tilde{D}(k) = \frac{1}{|\mathbf{k}|^2 - n^2(k^0)^2 - i\epsilon} +$$

$$+ \int_{4m^2}^{\infty} dM^2 \frac{a(M^2)}{|\mathbf{k}|^2 - n^2(k^0)^2 + \frac{M^2c^2}{\hbar^2} - i\epsilon}, \tag{2}$$

where the last term in equation (2) is derived on the virtual photon condition

$$|\mathbf{k}|^2 - n^2(k^0)^2 = -\frac{M^2c^2}{\hbar^2}, \tag{3}$$

where $n$ is the index of refraction of the medium. The weight function $a(M^2)$ has been derived in the following form (Dittrich, 1978; Schwinger, 1973):

$$a(M^2) = \frac{\alpha}{3\pi}\frac{1}{M^2}\left(1 + \frac{2m^2}{M^2}\right)\left(1 - \frac{4m^2}{M^2}\right)^{1/2}. \tag{4}$$

The x-representation of $D(k)$ in eq. (1) is as follows:

$$D_+(x - x') = \int \frac{(dk)}{(2\pi)^4} e^{ik(x-x')} D(k). \tag{5}$$

Or,

$$D_+(x - x') = \int \frac{(dk)}{(2\pi)^4} \frac{e^{ik(x-x')}}{|\mathbf{k}^2| - n^2(k^0)^2 - i\epsilon} =$$

$$= \frac{i}{c}\frac{1}{4\pi^2}\int_0^{\infty} d\omega \frac{\sin\frac{n\omega}{c}|\mathbf{x} - \mathbf{x}'|}{|\mathbf{x} - \mathbf{x}'|} e^{-i\omega|t-t'|}. \tag{6}$$

Now, with regard to the definition of x-representation (5) and (6) of the $D_+(x - x')$, we get the x-representation of the $\delta D_+$ in the following form:

$$\delta D_+(x - x') = \frac{i}{c}\frac{1}{4\pi^2}\int_{4m^2}^{\infty} dM^2 a(M^2)\times$$

$$\times \int d\omega \frac{\sin[\frac{n^2\omega^2}{c^2} - \frac{M^2c^2}{\hbar^2}]^{1/2}|\mathbf{x} - \mathbf{x}'|}{|\mathbf{x} - \mathbf{x}'|} e^{-i\omega|t-t'|}. \tag{7}$$

The function (7) differs from the the original function $D_+$ especially by the factor

$$\gamma = \left(\frac{\omega^2 n^2}{c^2} - \frac{M^2c^2}{\hbar^2}\right)^{1/2} \tag{8}$$

and by the additional mass-integral which involves the radiative corrections to the original photon processes. It was easily shown in case of the Čerenkov effect by author (Pardy, 1994a).

So, to involve the photoelectric effect with the dressed photon with electron positron pair we replace the wave function of photon $\exp(i\mathbf{k}\cdot\mathbf{x})$ by the function involving the radiative correction factor as follows:

$$e^{i\mathbf{k}\cdot\mathbf{x}} \to \int_{4m^2}^{\infty} dM^2 a(M^2) e^{i\boldsymbol{\kappa}\cdot x}, \tag{9}$$

where $\boldsymbol{\kappa}\cdot\mathbf{x} = \lambda|k||x|\cos\varphi$.

Let us consider here the alternative approach to the photoeffect which differs formally from Berestetzky approach. We mean the Davydov textbook approach. The probability of the emission of electron by the electromagnetic wave is then of the well-known form (Davydov, 1976):

$$dP = \frac{e^2 p}{8\pi^2\varepsilon_0\hbar m\omega}\left|\int e^{i(\boldsymbol{\kappa}-\mathbf{q})\cdot\mathbf{x}}(\mathbf{e}\cdot\nabla)\psi_0 dxdydz\right|^2 d\Omega = C|J|^2 d\Omega, \tag{10}$$

where the interaction for absorption of the electromagnetic wave is normalized to *one photon in the unit volume*, $\mathbf{e}$ is the polarization of the impinging photon, $\varepsilon_0$ is the dielectric constant of vacuum, $\psi_0$ is the basic state of and atom. We have denoted the integral in || by $J$ and the constant before || by C.

So, the main problem is to calculate the integral

$$J = \int e^{i(\boldsymbol{\kappa}\cdot\mathbf{x})}(\mathbf{e}\cdot\nabla)\psi_0 dxdydz; \quad \mathbf{K} = \boldsymbol{\kappa} - \mathbf{q}. \tag{11}$$

with the basic Landau function $\psi_0$ given by the equation (4).

Operator $(\hbar/i)\nabla$ is Hermitean and it means we can rewrite the last integrals as follows:

$$J = \frac{i}{\hbar}\mathbf{e}\cdot\int\left[\left(\frac{\hbar}{i}\nabla\right)e^{i(\mathbf{K}\cdot\mathbf{x})}\right]^*\psi_0 dxdydz, \tag{12}$$

which gives

$$J = i\mathbf{e}\cdot\mathbf{K}\int e^{-i(\mathbf{K}\cdot\mathbf{x})}\psi_0 dxdydz, \tag{13}$$

Let us consider the problem in the magnetic field where the motion of electron is in plain. Then, the integral in eq. (13) can be transformed using the cylindrical coordinates with

$$dxdydz = \varrho d\varrho d\varphi dz, \quad \varrho^2 = x^2 + y^2 \tag{14}$$

which gives for vector $\mathbf{K}$ fixed on the axis z with $\mathbf{K}\cdot\mathbf{x} = Kz$ and with physical condition $\mathbf{e}\cdot\kappa = 0$, expressing the physical situation where polarization is perpendicular to the direction of the wave propagation. So,

$$J = (i)(\mathbf{e}\cdot\mathbf{q})\int_0^\infty \varrho d\varrho\int_{-\infty}^{\infty} dz\int_0^{2\pi} d\varphi e^{-iKz}\psi_0. \tag{15}$$

Using

$$\psi_0 = A\exp\left(-B\varrho^2\right); \quad A = \left(\frac{m\omega_c}{2\pi\hbar}\right)^{1/2}; \quad B = \frac{m\omega_c}{4\hbar}; \qquad \omega_c = \frac{|e|H}{mc}. \tag{16}$$

The integral (15) is then

$$J = (-\pi i)\frac{A}{B}(\mathbf{e}\cdot\mathbf{q})\int_{-\infty}^{\infty} e^{-iKz}dz = (-\pi i)\frac{A}{B}(\mathbf{e}\cdot\mathbf{q})(2\pi)\delta(K). \tag{17}$$

Then,

$$dP = C|J|^2 d\Omega = 4\pi^4\frac{A^2}{B^2}C(\mathbf{e}\cdot\mathbf{q})^2\delta^2(\kappa)d\Omega. \tag{18}$$

Now, let be the angle $\Theta$ between direction $\boldsymbol{\kappa}$ and direction $\mathbf{q}$, and let be the angle $\Phi$ between planes $(\boldsymbol{\kappa},\mathbf{q})$ and $(\mathbf{e},\boldsymbol{\kappa})$. Then,

$$(\mathbf{e}\cdot\mathbf{q})^2 = q^2\sin^2\Theta\cos^2\Phi. \tag{19}$$

So, the differential probability of the emission of photons from the plane in the strong magnetic field is as follows:

$$dP = \frac{4e^2p}{\pi\varepsilon_0 m^2\omega\omega_c}\int_{4m^2}^{\infty} dM^2 a(M^2)\left[q^2\cos^2\Theta\sin^2\Phi\right]\delta^2(K)d\Omega; \quad \omega_c = \frac{|e|H}{mc}. \tag{20}$$

We can see that our result differs form the result for the original photoelectric effect which involves still the term

$$\frac{1}{(1-\frac{v}{c}\cos\Theta)^4}, \tag{21}$$

which means that the most intensity of the classical photoeffect is in the direction of the electric vector of the electromagnetic wave $(\Phi = \pi/2, \Theta = 0)$. While the nonrelativistic solution of the photoeffect in case of the Coulomb potential was performed by Stobbe (1930) and the relativistic calculation by Sauter (Sauter, 1931), the general magnetic photoeffect (with electrons moving in the magnetic field and forming atom) was not still performed in a such simple form. The delta term $\delta\cdot\delta$ represents the conservation law $|\boldsymbol{\kappa}-\mathbf{q}| = 0$ in our approximation.

# 8 H-aton in the Gibbons-Hawking thermal bath

The Gibbons-Hawking effect is the statement that a temperature can be associated to each solution of the Einstein field equations that contains a causal horizon. It is named after Gary Gibbons and Stephen William Hawking.

Schwarzschild spacetime contains an event horizon and so can be associated with temperature. In the case of Schwarzschild spacetime this is the temperature $T$ of a black hole of mass $M$, satisfying $T/M$ .

De Sitter space which contains an event horizon has the temperature $T$ proportional to the Hubble parameter $H$. We consider here the influence of the heat bath of the Gibbons-Hawking photons on the energy shift of H-atom electrons.

The considered problem is not in the scientific isolation, because some analogical problems are solved in the scientific respected journals. At present time it is a general conviction that there is an important analogy between black hole and the hydrogen atom. The similarity between black hole and the hydrogen atom was considered for instance by

Corda (2015a), who discussed the precise model of Hawking radiation from the tunneling mechanism. In this article an elegant expression of the probability of emission is given in terms of the black hole quantum levels. So, the system composed of Hawking radiation and black hole quasi-normal modes introduced by Corda (2015b) is somewhat similar to the semiclassical Bohr model of the structure of a hydrogen atom.

The time dependent Schrödinger equation was derived for the system composed by Hawking radiation and black hole quasi-normal modes (Corda, 2015c). In this model, the physical state and the correspondent wave function are written in terms of an unitary evolution matrix instead of a density matrix. Thus, the final state is a pure quantum state instead of a mixed one and it means that there is no information loss. Black hole can be well defined as the quantum mechanical systems, having ordered, discrete quantum spectra, which respect 't Hooft's assumption that Schrödinger equations can be used universally for all dynamics in the universe.

Thermal photons by Gibbons and Hawking form so called blackbody, which has the distribution law of photons derived in 1900 by Planck (1900, 1901), (Schöpf, 1978). The derivation was based on the investigation of the statistics of the system of oscillators inside of the blackbody. Later Einstein (1917) derived the Planck formula from the Bohr model of atom where electrons have the discrete energies and the energy of the emitted photons are given by the Bohr formula $\hbar\omega = E_i - E_f$, $E_i, E_f$ are the initial and final energies of electrons.

Now, let us calculate the modified Coulomb potential due to blackbody. The starting point of the determination of the energy shift in the H-atom is the potential $V_0(\mathbf{x})$, which is generated by nucleus of the H-atom. The potential at point $V_0(\mathbf{x} + \delta\mathbf{x})$, evidently is (Akhiezer, et al., 1953; Welton, 1948):

$$V_0(\mathbf{x} + \delta\mathbf{x}) = \left\{1 + \delta\mathbf{x}\nabla + \frac{1}{2}(\delta\mathbf{x}\nabla)^2 + ...\right\} V_0(\mathbf{x}). \tag{1}$$

If we average the last equation in space, we can eliminate so called the effective potential in the form

$$V(\mathbf{x}) = \left\{1 + \frac{1}{6}(\delta\mathbf{x})_T^2\Delta + ...\right\} V_0(\mathbf{x}), \tag{2}$$

where $(\delta\mathbf{x})_T^2$ is the average value of te square coordinate shift caused by the thermal photon fluctuations. The potential shift follows from eq. (2):

$$\delta V(\mathbf{x}) = \frac{1}{6}(\delta\mathbf{x})_T^2\Delta V_0(\mathbf{x}). \tag{3}$$

The corresponding shift of the energy levels is given by the standard quantum mechanical formula (Akhiezer, et al., 1953)

$$\delta E_n = \frac{1}{6}(\delta\mathbf{x})_T^2(\psi_n\Delta V_0\psi_n). \tag{4}$$

In case of the Coulomb potential, which is the case of the H-atom, we have

$$V_0 = -\frac{e^2}{4\pi|\mathbf{x}|}. \tag{5}$$

Then for the H-atom we can write

$$\delta E_n = \frac{2\pi}{3}(\delta \mathbf{x})^2_T \frac{e^2}{4\pi}|\psi_n(0)|^2, \tag{6}$$

where we used the following equation for the Coulomb potential

$$\Delta \frac{1}{|\mathbf{x}|} = -4\pi\delta(\mathbf{x}). \tag{7}$$

Motion of electron in electric field is evidently described by elementary equation

$$\delta\ddot{\mathbf{x}} = \frac{e}{m}\mathbf{E}_T, \tag{8}$$

which can be transformed by the Fourier transformation into the following equation

$$|\delta \mathbf{x}_{T\omega}|^2 = \frac{1}{2}\left(\frac{e^2}{m^2\omega^4}\right)\mathbf{E}^2_{T\omega}, \tag{9}$$

where the index $\omega$ concerns the Fourier component of above functions.

On the basis of the Bethe idea of the influence of vacuum fluctuations on the energy shift of electron (Bethe, 1947), the following elementary relations was used by Welton (1948), Akhiezer et al. (1953) and Berestetzky et al. (1989):

$$\frac{1}{2}\mathbf{E}^2_\omega = \frac{\hbar\omega}{2} \tag{10}$$

and in case of the thermal bath of the blackbody, the last equation is of the following form (Isihara, 1971):

$$\mathbf{E}^2_{T\omega} = \varrho(\omega) = \left(\frac{\hbar\omega^3}{\pi^2 c^3}\right)\frac{1}{e^{\frac{\hbar\omega}{kT}} - 1}, \tag{11}$$

because the Planck law in eq. (11) was written as

$$\varrho(\omega) = G(\omega) < E_\omega >= \left(\frac{\omega^2}{\pi^2 c^3}\right)\frac{\hbar\omega}{e^{\frac{\hbar\omega}{kT}} - 1}, \tag{12}$$

where the term

$$< E_\omega >= \frac{\hbar\omega}{e^{\frac{\hbar\omega}{kT}} - 1} \tag{13}$$

is the average energy of photons in the blackbody and

$$G(\omega) = \frac{\omega^2}{\pi^2 c^3} \tag{14}$$

is the number of electromagnetic modes in the interval $\omega, \omega + d\omega$.

Then,

$$(\delta \mathbf{x}_{T\omega})^2 = \frac{1}{2}\left(\frac{e^2}{m^2\omega^4}\right)\left(\frac{\hbar\omega^3}{\pi^2 c^3}\right)\frac{1}{e^{\frac{\hbar\omega}{kT}} - 1}, \tag{15}$$

where $(\delta \mathbf{x}_{T\omega})^2$ involves the number of frequencies in the interval $(\omega, \omega + d\omega)$.

So, after some integration, we get

$$(\delta \mathbf{x})^2_T = \int_{\omega_1}^{\omega_2} \frac{1}{2}\left(\frac{e^2}{m^2\omega^4}\right)\left(\frac{\hbar\omega^3}{\pi^2 c^3}\right)\frac{d\omega}{e^{\frac{\hbar\omega}{kT}}-1} = \frac{1}{2}\left(\frac{e^2}{m^2}\right)\left(\frac{\hbar}{\pi^2 c^3}\right)F(\omega_2-\omega_1), \quad (16)$$

where $F(\omega)$ is the primitive function of the omega-integral

$$J = \frac{1}{\omega}\frac{1}{e^{\frac{\hbar\omega}{kT}}-1}, \quad (17)$$

which cannot be calculated by the elementary integral methods and it is not involved in the tables of integrals.

Frequencies $\omega_1$ and $\omega_2$ will be determined with regard to the existence of the fluctuation field of thermal photons. It was determined in case of the Lamb shift (Bethe, 1947 ; Welton, 1947) by means of the physical analysis of the interaction of the Coulombic atom with the surrounding fluctuation field. We suppose here that the Bethe and Welton arguments are valid and so we take the frequencies in the Bethe-Welton form. In other words, electron cannot respond to the fluctuating field if the frequency which is much less than the atom binding energy given by the Rydberg constant (Rohlf, 1994) $E_{Rydberg} = \alpha^2 mc^2/2$. So, the lower frequency limit is

$$\omega_1 = E_{Rydberg}/\hbar = \frac{\alpha^2 mc^2}{2\hbar}, \quad (18)$$

where $\alpha \approx 1/137$ is so called the fine structure constant.

The specific form of the second frequency follows from the elementary argument, that we expect the effective cutoff, since we must neglect the relativistic effect in our non-relativistic theory. So, we write

$$\omega_2 = \frac{mc^2}{\hbar}. \quad (19)$$

If we take the thermal function of the form of the geometric series

$$\frac{1}{e^{\frac{\hbar\omega}{kT}}-1} = q(1+q^2+q^3+.....); \quad q = e^{-\frac{\hbar\omega}{kT}}, \quad (20)$$

$$\int_{\omega_1}^{\omega_2} q(1+q^2+q^3+.....)\frac{1}{\omega}d\omega = \ln|\omega| + \sum_{k=1}^{\infty}\frac{(-\frac{\hbar\omega}{kT})^k}{k!k} + ....; \quad q = e^{-\frac{\hbar\omega}{kT}} \quad (21)$$

and the first thermal contribution is

$$Thermal\ contribution = \ln\frac{\omega_2}{\omega_1} - \frac{\hbar}{kT}(\omega_2-\omega_1), \quad (22)$$

Then, with eq. (6)

$$\delta E_n \approx \frac{2\pi}{3}\left(\frac{e^2}{m^2}\right)\left(\frac{\hbar}{\pi^2 c^3}\right)\left(\ln\frac{\omega_2}{\omega_1} - \frac{\hbar}{kT}(\omega_2-\omega_1)\right)|\psi_n(0)|^2, \quad (23)$$

where (Sokolov et al., 1962)

$$|\psi_n(0)|^2 = \frac{1}{\pi n^2 a_0^2} \quad (24)$$

with

$$a_0 = \frac{\hbar^2}{me^2}. \tag{25}$$

Let us only remark that the numerical form of eq. (23) has deep experimental astrophysical meaning.

In article by author (Pardy, 1994), which is the continuation of author articles on the finite-temperature Cherenkov radiation and gravitational Cherenkov radiation (Pardy, 1989a; ibid., 1989b), the temperature Green function in the framework of the Schwinger source theory (Schwinger, 1970) was derived in order to determine the Coulomb and Yukawa potentials at finite-temperature using the Green functions of a photon with and without radiative corrections, and then by considering the processes expressed by the Feynman diagrams.

The determination of potential at finite temperature is one of the problems which form the basic ingredients of the quantum field theory (QFT) at finite temperature. This theory was formulated some years ago by Dolan and Jackiw (1974), Weinberg (1974) and Bernard (1974) and some of the first applications of this theory were the calculations of the temperature behavior of the effective potential in the Higgs sector of the standard model.

Information on the systematic examination of the finite temperature effects in quantum electrodynamics (QED) at one-loop order was given by Donoghue, Holstein and Robinett (1985). Partovi (1994) discussed the QED corrections to Planck's radiation law and photon thermodynamics,

A similar discussion of QED was published by Johansson, Peressutti and Skagerstam (1986) and Cox et al. (1984).

So, We considered here the thermal gas corresponding to the Gibbons-Hawking theory of space-time (at temperature T) as the preamble for new experiments for the determination of the energy shift of H-atom electrons interacting with the Gibbons-Hawking thermal gas. It is not excluded, that the observations performed by the well educated astro-experts will be the crucial ones.

# 9 The Planck formula in dielectric crystal

It is physically meaningful to consider, in quantum theory of light and quantum theory of solids, dielectric crystalline medium with phonons which is inserted in the Planck blackbody photon gas. It means that photon gas of the blackbody surrounding the dielectric crystalline medium with with index of refraction $n$ flows into such crystal and initiate the quantum osmotic pressure of photons as solvent and phonons as solute.

The classical osmosis is the spontaneous passage of solvent molecules through a partially permeable membrane separating two solutions of different concentration into a region of higher solute concentration of solute, in order to equalize the solute concentrations on the two sides. The physical law which controll the osmotic pressure is so called van't Hoff's equation (published in 1885):

$$p = i\frac{C}{\mu}RT, \tag{1}$$

where $p, i, C, \mu, R, T$ are pressure, van't Hoff factor, concentration of solute, mollar mass, thermodynamic gas constant and temperature, and concentration is defined by formula $C = m/V$, where $m$ is mass of solute in volume $V$. We consider here the quantum osmosis with photons and phonons and with the semi-permeable membrane for photons which is the surface of the dielectric crystal.

The derivation of the van't Hoff formula using the thermodynamic potential can be found in the textbooks on thermodynamics and statistical physics (Landau et al., 1980). The derivation of the osmotical pressure from rigorous statistical physics was given by Isihara (1971). On the other hand, the quantum theory of osmosis was not published. A Duth physical and organic chemist van't Hoff presented his Nobelian theory long time before the introduction of photons into physics by Max Planck, Lewis and Einstein and before the introduction of phonons into solid state physics by Einstein and Debye. So, the problem of the osmotic pressure in the Planck blackbody with the dielectric medium arises as the problem of modern physics.

The dielectric crystal with photons is called here by term Planck dielectric blackbody. Inside of the dielectric medium with index of refraction $n$, the spectral radiation formula is modified and we derive in the next part mathematical form of the spectrum of such dielectric blackbody. The derivation of the spectral formula is based on the original Planck spectral formula which was rederived by Einstein (1917).

The spectral distribution of the blackbody does not depend on the specific atomic composition of the blackbody and it means the formula (7) must be so called the Planck formula:

$$\varrho_\omega = \frac{\hbar\omega^3}{\pi^2 c^3}\frac{1}{e^{\frac{\hbar\omega}{kT}} - 1}. \tag{2}$$

The internal density energy of the blackbody gas is given by integration of the last equation over all frequencies $\omega$, or

$$u = \int_0^\infty \varrho(\omega)d\omega = aT^4; \quad a = \frac{\pi^2 k^4}{15\hbar^3 c^3}. \tag{3}$$

and the pressure of photons inside the blackbody follows from the electrodynamic situation inside blackbody as follows:

$$p = \frac{u}{3} \qquad (4).$$

We suppose here that inside of the Planck blackbody there is the dielectric crystal with the index of refraction $n(\omega)$. Then, the wave vector of photon inside the dielectric medium is given by known formula

$$q = n(\omega)\frac{\omega}{c}. \tag{5}$$

The number of light modes in the interval $q, q+dq$ inside of the dielectric in the volume $V$ is $Vq^2dq/\pi^2$. After differentiation of formula (5) we get with $d\ln\omega = d\omega/\omega$

$$dq = \frac{1}{c}[n(\omega) + \omega\frac{dn(\omega)}{d\omega}]d\omega = \frac{n(\omega)}{c}\frac{d\ln[n(\omega)\omega]}{d\ln\omega}d\omega. \tag{6}$$

Then, it is easy to see that the number of states in the interval $\omega, \omega + d\omega$ of the electromagnetic vibrations in the volume $V$ is

$$Vg(\omega)d\omega = \frac{V}{\pi^2}\left(\frac{n(\omega)}{c}\right)^3 \frac{d\ln[n(\omega)\omega]}{d\ln\omega}d\omega. \tag{7}$$

If we multiply the last formula by the average energy of the harmonic oscillator,

$$< E_\omega >= \frac{\hbar\omega}{e^{\frac{\hbar\omega}{kT}} - 1}, \tag{8}$$

we get the Planck formula for the blackbody with dielectric medium:

$$\varrho(\omega) = \frac{n^3(\omega)\omega^2}{\pi^2 c^3}\frac{d\ln[n(\omega)\omega]}{d\ln\omega}\frac{\hbar\omega}{e^{\frac{\hbar\omega}{kT}} - 1}, \tag{9}$$

where for $n = 1$, we get exactly formula (2).

## 9.1 The oscillator model of the index of refraction

This model follows from the classical theory of dispersion, which is based on the vibration equation of electron in an atom

$$\ddot{x} + \gamma\dot{x} + \omega_0^2 x = \frac{e}{m}E_0\cos\omega t, \tag{10}$$

where $\gamma$ is the oscillator constant and $\omega_0$ is the basic frequency of oscillator. The symbol $\omega$ is the frequency of the applied electric field. The index of refraction following from eq (17) is given by the formula (Garbuny, 1965)

$$n = 2\pi N\frac{e^2}{m}\frac{\omega_0^2 - \omega^2}{(\omega_0^2 - \omega^2)^2 + \gamma^2\omega^2}, \tag{11}$$

where $N$ is number of electrons in the unit of volume.

In case of electrons with basic frequencies $\omega_1, \omega_2, \omega_3, \omega_4 ... \omega_n$, the last refraction index can be generalized to form more complex mathematical object. We consider here, to be pedagogical clear, only one oscillator with one basic frequency. Nevertheless it is possible consider arbitrary dielectric material with the phenomenological index of refraction.

Now the question arises, if the dielectric blackbody can be considered as the solution composed from atoms, phonons and photons where the osmotic pressure play some role. We had accepted this hypothesis as the correct one.

## 9.2 The osmosis in dielectric blackbody

Phonons were introduced in the crystal physics by Einstein in order to derive the adequate formula for he specific heat. The Einstein formula was generalized and improved by Debye who derived the formula for the average energy of phonons in a crystal in the interval of temperatures $\Theta - \delta < T < \Theta + \delta$ ($\delta$ is some parameter) as follows (Rumer et al., 1977):

$$U = N\varepsilon_0 + 3NTD\left(\frac{\Theta}{T}\right), \tag{12}$$

where $\varepsilon_0 = (9/8)\hbar\omega_{max}$, where

$$\omega_{max} = 2\pi v \left(\frac{3N}{4\pi V}\right)^{1/3} \tag{13}$$

and $D(x)$ is so called the Debye wave function of the following structure:

$$D(x) = \frac{3}{x^3}\int_0^x \frac{y^3}{e^y - 1}dy, \tag{14}$$

and the critical temperature $\Theta$ was derived by Debye in the following form:

$$\Theta = v\left(\frac{6\pi^2 N}{V}\right)^{1/3}, \tag{15}$$

with $v$ being velocity of sound waves defined in the theory of elasticity of the crystal.

Let us compare the internal energies of the pure blackbody and dielectric blackbody and then let us compare the pressure inside of the pure blackbody and inside the dielectric blackbody.

For pure blackbody, we have $u = aT^4$ and for model with $n$ given by eq. (11) we have

$$u = \int_0^\infty \varrho_n(\omega)d\omega = \int_0^\infty \varrho_n(\omega)\frac{n^3(\omega)\omega^2}{c^3}\frac{d\ln[n(\omega)\omega]}{d\ln\omega}\frac{\hbar\omega}{e^{\frac{\hbar\omega}{kT}} - 1}d\omega. \tag{16}$$

Because the dielectric medium is permeable for photons and not for phonons (the photon osmosis), the outer pressure is equal to the photon gas pressure in the dielectric blackbody, or $p(n) = u(n)/3 = u/3$. So,

$$\int_0^\infty \varrho_n(\omega)d\omega = u/3 = \frac{aT^4}{3}, \tag{17}$$

or,

$$\int_0^\infty \frac{n^3(\omega)\omega^2}{\pi^2c^3}\frac{d\ln[n(\omega)\omega]}{d\ln\omega}\frac{\hbar\omega}{e^{\frac{\hbar\omega}{kT_{diel}}} - 1}d\omega = \frac{aT^4}{3}, \tag{18}$$

where we introduced the dielectric temperature $T_{diel}$, which physically means that the temperature of dielectric blackbody is not the same as the temperature of the bath of vacuum blackbody photons. The last equation is the integral equation for function $T_{diel}$ and in general represents very difficult mathematical problem of the future physics of the dielectric blackbody. The experimental verification of the last equation will be also the crucial problem of photon physics.

In the most simple case with $n = const$, we get after some algebraic operation, that the temperature dielectric blackbody surrounded by the vacuum blackbody is given by the formula

$$T_{diel} = \frac{T}{\sqrt[4]{n^3}}. \tag{19}$$

The last formula can form the goal of the experimenters working in the blackbody radiation physics. The dielectric as the osmotic membrane plays the role of the Maxwell demonic refrigerator. The second possibility is to put $n = n(T)$ in order to get the integral equation for the dependence of the index of refraction on temperature. However, it seems that this assumption is not physically adequate.

In case of the dielectric Debye crystal, the equation of state is (Rumer et al., 1977)

$$p = \left(\frac{U_{phon}}{\Theta} - \frac{9}{4}N\right)\frac{d\Theta}{dV}, \tag{20}$$

where $V$ and $N$ is volume and number of oscillators in crystal. The difference $\Delta p = p(T) - p(T_{diel})$ is the osmotic pressure caused by the photon flow.

In case of the two-dimensional crystal, the internal phonon energy is (Rumer et al., 1977)

$$U_{2D-phon} = \frac{4}{3}N\Theta\left[1 + \left(\frac{T}{\Theta}\right)^3 \int_0^{\Theta/T} \frac{y^2}{e^y - 1}dy\right]. \tag{21}$$

and

$$\Theta = 2\pi v\left(\frac{N}{\pi\sigma}\right)^{1/2}, \tag{22}$$

where $\sigma$ is the area of the 2D crystal (e. g. graphene, which is the carbon sheet), instead of $d\Theta/dV$ is $d\Theta/d\sigma$ and 9/4 must be replaced by the adequate constant. The osmotic temperature of the 2-dimensional and 1-dimensional dielectric crystal is an analogue of the 3-dimensional case and can be derived from the formulas by author article (Pardy, 2015b).

We know that the classical osmosis is the physical phenomenon in the system with solute, solvent, solution and semi-permeable membrane. It plays fundamental role in biological and physiological systems, where for instance the photosynthesis in plants is not possible without water and photon osmosis and human being does not exist without liquid osmosis.

Isihara (1971) derived from the statistical physics the following formula for the osmotic pressure of the two-component statistical system:

$$p = kT\frac{\partial[\ln(\Xi/\Xi_0)]}{\partial V}, \tag{23}$$

where $\Xi$ and $\Xi_0$ are the big statistical sums of solute and solvent. The explicit mathematical form of the formula is sophisticated and the derivation of the van't Hoff formula is not elementary.

The theory of phonon-photon dielectric blackbody is the preamble for experiments for the determination of the osmotic process as the consequence of the quantum properties of the phonon-photon gas. The role of phonon-photon osmosis in biological and physiological systems is crucial. The phonon-photon osmotic pressure plays probably substantial negative role in the formation and in the development of skin cancer.

It is not excluded, that the experiments with the quantum osmosis in plasma with magnetic field as semi-permeable osmotic membrane, will play crucial role in the fusion reactor physics.

# 10 The Casimir effect at finite temperature

The Casimir effect, or, Casimir-Polder force are physical forces arising from a quantized field. They are named after the Dutch physicist Hendrik Casimir who predicted it in

1948.

The Casimir effect is an interaction between disjoint neutral bodies caused by the fluctuations of the electrodynamic vacuum. It can be explained by considering the normal modes of electromagnetic fields, which explicitly depend on the boundary (or matching) conditions on the interacting bodies surfaces. At the most basic level, the field at each point in space is a simple quantum harmonic oscillator. Excitations of the field (oscillator) correspond to the elementary particles of particle physics. However, even the vacuum has a complex structure, all calculations must be made in relation to such model of the vacuum.

The Casimir effect at finite temperature is the integral part of the finite-temperature ($T \neq 0$) QED, QFT and also quantum chromodynamics (QCD) which usually deal with the specific processes in the heat bath of photons or other particles (Donoghue et al., 1985). The heat bath can be formed by different kinds of elementary particles and so such different hot media have a different influence on the same specific physical process developing in the media. We consider here the influence of the heat bath photons on the energy shift inside of the thermal box, leading to the attraction of the capacitor plates with a separation $a$.

## 10.1 Casimir effect at zero temperature

In order to understand the Casimir effect at zero temperature, we follow Holstein (1992) and imagine two capacitor plates with a separation $a$. The field modes permitted by the boundary condition have the electrical intensity vanishing on the surface on the plates. If the normal to the surface defines the z-direction, then for the propagation in this direction wavelength varies from zero to $a$. If the zero point energy of the oscillators representing the quantum field is $\hbar\omega_k/2$ (Berestetsky et al., 1989), then the total energy between the plates is given by the formula

$$U(a) = \sum_k \frac{1}{2}\hbar\omega_k. \tag{1}$$

When the plate separation is increased, more modes are permitted so the energy is increasing function of separation $a$. In case that the separation $a$ is lowered, then the energy is also lowered which means that the change of energy is force of the form:

$$F = -\frac{\partial U(a)}{\partial a}. \tag{2}$$

The force has been detected for instance by Sparnay (1958) and represents the macroscopic manifestation of the validity of quantum field theory.

The quantitative evaluation of the Casimir force is as follows. Let be wave numbers $k_x, k_z$ in the $x, y$ direction. Then the density of states is given by the formula

$$A \int \frac{d^2k}{(2\pi)^2}, \tag{3}$$

where $A$ is the area of the plates.

In the $z$-direction, on the other hand, the boundary conditions $\mathbf{E}(0) = \mathbf{E}(a) = 0$ requires

$$E \sim \sin(k_z z) \tag{4}$$

with

$$k_z = \frac{n\pi}{a}; \qquad n = 1, 2, .... \tag{5}$$

The frequencies are

$$\omega_k = \sqrt{k_x^2 + k_y^2 + \left(\frac{n\pi}{a}\right)^2}. \tag{6}$$

The total vacuum energy of photons (with two polarizations) between plates is evidently as follows:

$$U(a) = 2\sum_{n=1}^{\infty} A \int \frac{d^2k}{(2\pi)^2}\frac{1}{2}\omega_k. \tag{7}$$

Defining

$$k = \sqrt{k_x^2 + k_y^2}, \tag{8}$$

we have from eq. (5)

$$kdk = \omega d\omega \tag{9}$$

and the new mathematical form of the total intermediate vacuum energy is

$$U(a) = A\sum_{n=1}^{\infty}\frac{1}{2\pi}\int_{\frac{n\pi}{a}}^{\infty} d\omega\omega^2. \tag{10}$$

Using the cutoff operation with $\exp(-\varepsilon\omega)$, we get the following formulas:

$$U(a) = \frac{A}{2\pi}\sum_{n=1}^{\infty}\int_{\frac{n\pi}{a}}^{\infty} d\omega\omega^2 e^{-\varepsilon\omega} = \frac{A}{2\pi}\frac{d^2}{d\varepsilon^2}\sum_{n=1}^{\infty}\int_{\frac{n\pi}{a}}^{\infty} d\omega e^{-\varepsilon\omega} =$$

$$\frac{A}{2\pi}\frac{d^2}{d\varepsilon^2}\sum_{n=1}^{\infty}\frac{1}{\varepsilon}e^{-\frac{n\pi\varepsilon}{a}} = \frac{A}{2\pi}\frac{d^2}{d\varepsilon^2}\frac{1}{\varepsilon}\left(\frac{1}{1-e^{\frac{\varepsilon\pi}{a}}} - 1\right). \tag{11}$$

After application the formula with the Bernoulli numbers $B_n$ (Prudnikov et al., 1984)

$$\frac{1}{1-e^{-t}} = -\sum_{n=1}^{\infty} B_n \frac{t^{n-1}}{n!}, \tag{12}$$

we get for $\varepsilon \to 0$ the final formula for the attraction of two plates immersed in the quantum vacuum (Holstein, 1992):

$$\frac{1}{A}F = -\frac{\partial}{\partial a}\frac{1}{A}U(a) = -\frac{\pi^2}{240a^4}. \tag{13}$$

Now, we can approach the calculation of the attractive force due to the photons of the blackbody sea.

## 10.2 The thermal Casimir effect due to blackbody photons

The blackbody photons are supposed in the box with the edges $l_l$, $l_2$, $l_3$ and the situation is the analogue of the quantum mechanical particle inside such box. However with regard to the fact that the photon gas has the temperature $T$, it is necessary to perform the following transformation to the thermodynamical system in the box:

$$U(a) = \sum_k \frac{1}{2}\hbar\omega_k \to \sum_k \left(\frac{\omega_k^2}{\pi c^3}\right) \frac{\hbar\omega_k}{e^{\frac{\hbar\omega_k}{k_B T}} - 1} \tag{14}$$

with

$$\omega_k = \omega_{n_1,n_2,n_3} = \sqrt{\left(\frac{n_1\pi}{l_1}\right)^2 + \left(\frac{n_2\pi}{l_2}\right)^2 + \left(\frac{n_3\pi}{l_3}\right)^2}. \tag{15}$$

So, the energy of photons in the photon sea is

$$U(a) = \sum_{n_1,n_2,n_3} \left(\frac{\omega_{n_1,n_2,n_3}^2}{\pi c^3}\right) \frac{\hbar\omega_{n_1,n_2,n_3}}{e^{\frac{\hbar\omega_{n_1,n_2,n_3}}{k_B T}} - 1}. \tag{16}$$

It is elementary statement that if $l_1 \to \infty, l_2 \to \infty, l_3 \to \infty$, we get the classical Planck distribution

$$\varrho(\omega) \to \left(\frac{\omega^2}{\pi c^3}\right) \frac{\hbar\omega}{e^{\frac{\hbar\omega}{k_B T}} - 1} \tag{17}$$

with (Feynman, 1972; Isihara, 1971)

$$U(blackbody) = \int_0^\infty \varrho(\omega) d\omega = \sigma T^4; \quad \sigma = \frac{\pi^2 (k_B T)^4}{15\hbar^3 c^3}. \tag{18}$$

The force in the x-direction is

$$F_x = -\frac{\partial U(l_1, l_2, l_3}{\partial l_1} = \sum_{n_1,n_2,n_3} \left(\frac{\hbar}{\pi c^3}\right) \left(\frac{n_1\pi}{l_1}\right)^2 \frac{1}{l_1} \quad \times$$

$$\left[\frac{3\omega}{e^{\frac{\hbar\omega}{k_B T}} - 1} - \frac{\omega^2 e^{\frac{\hbar\omega}{k_B T}}}{\left(e^{\frac{\hbar\omega}{k_B T}} - 1\right)^2} \frac{\hbar}{k_B T}\right]. \tag{19}$$

The force in the y-direction is

$$F_y = -\frac{\partial U(l_1, l_2, l_3)}{\partial l_2} = \sum_{n_1,n_2,n_3} \left(\frac{\hbar}{\pi c^3}\right) \left(\frac{n_2\pi}{l_2}\right)^2 \frac{1}{l_2} \quad \times$$

$$\left[\frac{3\omega}{e^{\frac{\hbar\omega}{k_B T}} - 1} - \frac{\omega^2 e^{\frac{\hbar\omega}{k_B T}}}{\left(e^{\frac{\hbar\omega}{k_B T}} - 1\right)^2} \frac{\hbar}{k_B T}\right] \tag{20}$$

and the force in the z-direction is

$$F_z = -\frac{\partial U(l_1,l_2,l_3)}{\partial l_3} = \sum_{n_1,n_2,n_3} \left(\frac{\hbar}{\pi c^3}\right)\left(\frac{n_3\pi}{l_3}\right)^2 \frac{1}{l_3} \quad \times$$

$$\left[\frac{3\omega}{e^{\frac{\hbar\omega}{k_BT}}-1} - \frac{\omega^2 e^{\frac{\hbar\omega}{k_BT}}}{\left(e^{\frac{\hbar\omega}{k_BT}}-1\right)^2}\frac{\hbar}{k_BT}\right]. \tag{21}$$

The specific pressure on the unit area $l_2l_3$, $l_1l_3$, $l_1l_2$. is

$$p_{23} = \frac{1}{l_2l_3}F_x = -\frac{1}{l_2l_3}\frac{\partial U(l_1,l_2,l_3)}{\partial l_1}, \tag{22}$$

$$p_{13} = \frac{1}{l_1l_3}F_y = -\frac{1}{l_1l_3}\frac{\partial U(l_1,l_2,l_3)}{\partial l_2}, \tag{23}$$

$$p_{12} = \frac{1}{l_1l_2}F_z = -\frac{1}{l_1l_2}\frac{\partial U(l_1,l_2,l_3)}{\partial l_3}. \tag{24}$$

In case of the equal edges of the thermal bath i.e. $l_1 = l_2 = l_3 = l$, the specific pressures are equal and it means that

$$p = \frac{1}{3l^5}\sum_{n_1,n_2,n_3}\left(\frac{\hbar}{\pi c^3}\right)\left[\left(\frac{n_1\pi}{l}\right)^2 + \left(\frac{n_2\pi}{l}\right)^2 + \left(\frac{n_3\pi}{l}\right)^2\right] \quad \times$$

$$\left[\frac{3\omega}{e^{\frac{\hbar\omega}{k_BT}}-1} - \frac{\omega^2 e^{\frac{\hbar\omega}{k_BT}}}{\left(e^{\frac{\hbar\omega}{k_BT}}-1\right)^2}\frac{\hbar}{k_BT}\right]. \tag{25}$$

Let us remark that the three-dimensional sums in eqs. (16), (19–22), (23–25) is not easy to calculate because they are not considered as the integral part of the standard mathematics. So, we can simplify the calculation by the so called continual limit. In other words, we perform replacing of the the sum by the $\omega$-integral and for eq. (25) we get:

$$p = \frac{1}{3l^5}\left(\frac{\hbar}{\pi c^3}\right)\int_0^\infty d\omega\omega^2\left[\frac{3\omega}{e^{\frac{\hbar\omega}{k_BT}}-1} - \frac{\omega^2 e^{\frac{\hbar\omega}{k_BT}}}{\left(e^{\frac{\hbar\omega}{k_BT}}-1\right)^2}\frac{\hbar}{k_BT}\right]. \tag{26}$$

Now, we are prepared to evaluate the $\omega$-integral in the last formula. Putting

$$x = \frac{\hbar\omega}{k_BT}; \quad \omega = \frac{xk_BT}{\hbar}; \quad d\omega = dx\frac{k_BT}{\hbar}; \quad C = \frac{k_BT}{\hbar}, \tag{27}$$

we get equation in the following form:

$$p = \frac{1}{3l^5}\left(\frac{\hbar}{\pi c^3}\right)\int_0^\infty dxC^5\left[\frac{3x^3}{e^x-1} - \frac{x^4e^x}{(e^x-1)^2}\right]. \tag{28}$$

According to textbook (Rumer et al., 1977)

$$\int_0^\infty dx \frac{x^n}{e^x - 1} = \Gamma(n+1)\zeta(n+1). \tag{29}$$

and (Prudnikov et al., 1984)

$$\int_0^\infty dx \frac{x^{2n} e^x}{(e^x - 1)^2} = 2^{2n-1}\pi^4 |B_{2n}|. \tag{30}$$

In case of the specification of $n$, we get (Rumer et al., 1977)

$$\int_0^\infty dx \frac{x^3}{e^x - 1} = \Gamma(4)\zeta(4) = 3! \left(\frac{\pi^4}{90}\right) \tag{31}$$

and (Prudnikov et al., 1984)

$$\int_0^\infty dx \frac{x^4 e^x}{(e^x - 1)^2} = 2^3\pi^4 \left|-\frac{1}{30}\right| = 2^3\pi^4 \frac{1}{30}, \tag{32}$$

where

$$|B_4| = \left|-\frac{1}{30}\right| = 1/30 \tag{33}$$

follows from the general formula (12).

So, the final formula for the so called Casimir effect at finite temperature is the numerical form of the formula (28). Or,

$$p = \frac{1}{3l^5}\left(\frac{\hbar}{\pi c^3}\right)\left(\frac{k_B T}{\hbar}\right)^5 \left[3.3!\left(\frac{\pi^4}{90}\right) - 2^3\left(\frac{\pi^4}{30}\right)\right]. \tag{34}$$

The last author formula is the original one and it was not published in the scientific physical research journals. The submitted approach can be easily generalized to phonon thermal bath, magnon thermal bath and and so on, or astrophysical thermal bath.

## 10.3 The quantum pressure

We have seen how the thermal photons with the Planck blackbody statistics generated the Casimir effect at finite temperature. The motivation for considering such problem can be seen in quantum mechanics with the electron confined in the box with the infinite barriers at point 0 and $l$. Then, the energy levels of electron inside the box is (Sokolov et al. 1962)

$$E_n = \frac{\pi^2\hbar^2 n^2}{2ml^2} \tag{35}$$

and the corresponding wave function is

$$\psi_n = \sqrt{\frac{2}{l}} \sin\left(\pi n \frac{x}{l}\right). \tag{36}$$

The quantum pressure caused by the quantum mechanical motion of particle is obtained by the same operation as in the Casimir effect. Or,

$$F = -\frac{\partial E_n}{\partial l} = \frac{\pi^2\hbar^2 n^2}{ml^3}. \quad (37)$$

In case that the thermal box is three dimensional, we get (Sokolov et al., 1962 )

$$E_{n_1,n_2,n_3} = \frac{\pi^2\hbar^2}{2m}\left[\left(\frac{n_1}{l_1}\right)^2 + \left(\frac{n_2}{l_2}\right)^2 + \left(\frac{n_3}{l_3}\right)\right] \quad (38)$$

and the corresponding wave function is

$$\psi_{n_1,n_2,n_3} = \sqrt{\frac{8}{l_1 l_2 l_3}}\sin\left(\pi n_1\frac{x}{l_1}\right)\sin\left(\pi n_2\frac{x}{l_2}\right)\sin\left(\pi n_3\frac{x}{l_3}\right). \quad (39)$$

The corresponding pressures are

$$p_{23} = -\frac{1}{l_2 l_3}\frac{\partial E_{n_1,n_2,n_3}}{\partial l_1} \quad (40)$$

$$p_{13} = -\frac{1}{l_1 l_3}\frac{\partial E_{n_1,n_2,n_3}}{\partial l_2} \quad (41)$$

$$p_{12} = -\frac{1}{l_1 l_2}\frac{\partial E_{n_1,n_2,n_3}}{\partial l_3}. \quad (42)$$

Let us only remark that the quantum pressure derived here is the perfect proof that the wave function in quantum mechanics is physical reality independent on the human mind, and not only mathematical object. The wave function is in such a way the objective form of matter, where matter is continuum which forms Universe.

The article is the continuation of the previous and related problems in the finite-temperature physics published by author (Pardy, 1989a, 1989b, 1994b, 2013a, 2013b).

Information on the systematic examination of the finite temperature effects in quantum electrodynamics (QED) at one-loop order was given by Donoghue, Holstein and Robinett (1985). They have treated the calculation of mass, charge, wave function renormalization and so on, and demonstrated the running of the coupling constant at finite temperature and discussed the normalized vertex function and the energy momentum tensor.

# 11 Cherenkov effect in the two-dimensional medium

The fast moving charged particle in a medium when its speed is faster than the speed of light in this medium produces electromagnetic radiation which is called the Vavilov-Čerenkov radiation.

The prediction of Cherenkov radiation came long ago. Heaviside (1889) investigated the possibility of a charged object moving in a medium faster than electromagnetic waves in the same medium becomes a source of directed electromagnetic radiation. Kelvin (1901) presented an idea that the emission of particles is possible at a speed greater than that of light. Somewhat later, Sommerfeld (1904) proposed the hypothetical radiation with a sharp angular distribution. However, in fact, from experimental point of view, the electromagnetic Cherenkov radiation was first observed in the early 1900's by experiments developed by Marie and Pierre Curie when studying radioactivity emission. In essence they observed the emission of a bluish-white light from transparent substances in the neighborhood of strong radioactive source. But the first attempt to understand the origin of this was made by Mallet (1926, 1929a, 1929b) who observed that the light emitted by a variety of transparent bodies placed close to a radioactive source always had the same bluish-white quality, and that the spectrum was continuous, with no line or band structure characteristic of fluorescence.

Unfortunately, these investigations were forgotten for many years. Cherenkov (or, Čerenkov) experiments was performed at the suggestion of Vavilov who opened a door to the true physical nature of this effect[1] (Bolotovsky, 2009).

This radiation was first theoretically interpreted by Tamm and Frank (1937) in the framework of the classical electrodynamics. The source theoretical description of this effect was given by Schwinger et al. (1976) at the zero temperature regime and the classical spectral formula was generalized to the finite temperature situation and for the massive photons by autor (Pardy, 1989a, 1997b). The Vavilov-Cherenkov effect was also used by author (Pardy, 1997) to possible measurement of the Lorentz contraction.

We derive, in the following text, by the Schwinger source theory method (Schwinger, 1970), the power spectrum of photons, generated by charged particle moving within 2D sheet, with index of refraction n. Some graphene-like structures, for instance graphene with implanted ions, or, also 2D-glasses, are dielectric media, enabling the experimental realization of the Vavilov-Cherenkov radiation. The relation of the Vavilov-Cherenkov radiation to LED, where the 2D the additional dielectric sheet is the integral part of LED, is discussed. It is not excluded that LEDs with the 2D dielectric sheets will be the crucial components of detectors in experimental particle physics.

## 11.1 Source theory of the Vavilov-Cherenkov effect

Let us start with the three dimensional source theory formulation of the problem. Source theory (Schwinger et al., 1976) is the theoretical construction which uses quantum-mechanical particle language. Initially it was constructed for description of the particle physics situations occurring in the high-energy physics experiments. However, it was found that the original formulation simplifies the calculations in the electrodynamics and gravity where the interactions are mediated by photon or graviton respectively.

The basic formula in the source theory is the vacuum to vacuum amplitude:

$$< 0_+|0_- >= e^{\frac{i}{\hbar}W(S)}, \tag{1}$$

where the minus and plus tags on the vacuum symbol are causal labels, referring to any time before and after space-time region where sources are manipulated. The exponential form is introduced with regard to the existence of the physically independent experimental arrangements which has a simple consequence that the associated probability amplitudes multiply and corresponding $W$ expressions add.

The electromagnetic field is described by the amplitude (1) with the action

$$W(J) = \frac{1}{2c^2}\int (dx)(dx')J^\mu(x)D_{+\mu\nu}(x-x')J^\nu(x'), \tag{2}$$

[1]So, the adequate name of this effect is the Vavilov-Cherenkov effect, (or, Čerenkov effect). In the English literature, however, it is usually called the Cherenkov effect.

where the dimensionality of $W(J)$ is the same as the dimensionality of the Planck constant $\hbar$. $J_\mu$ is the charge and current densities, where quantity $J_\mu$ is conserved. The symbol $D_{+\mu\nu}(x-x')$, is the photon propagator and its explicit form will be determined later.

It may be easy to show that the probability of the persistence of vacuum is given by the following formula (Schwinger et al., 1976):

$$|<0_+|0_->|^2 = \exp\{-\frac{2}{\hbar}\mathrm{Im}\,W\} \stackrel{d}{=} \exp\{-\int dt d\omega \frac{P(\omega,t)}{\hbar\omega}\}, \tag{3}$$

where we have introduced the so called power spectral function $P(\omega,t)$ (Schwinger et al., 1976). In order to extract this spectral function from $\mathrm{Im}\,W$, it is necessary to know the explicit form of the photon propagator $D_{+\mu\nu}(x-x')$.

The electromagnetic field is described by the four-potentials $A^\mu(\varphi,\mathbf{A})$ and it is generated, including a particular choice of gauge, by the four-current $J^\mu(c\varrho,\mathbf{J})$ according to the differential equation, (Schwinger et al., 1976):

$$\left(\Delta - \frac{\mu\varepsilon}{c^2}\frac{\partial^2}{\partial t^2}\right)A^\mu = \frac{\mu}{c}\left(g^{\mu\nu} + \frac{n^2-1}{n^2}\eta^\mu\eta^\nu\right)J_\nu \tag{4}$$

with the corresponding Green function $D_{+\mu\nu}$:

$$D_+^{\mu\nu} = \frac{\mu}{c}(g^{\mu\nu} + \frac{n^2-1}{n^2}\eta^\mu\eta^\nu)D_+(x-x'), \tag{5}$$

where $\eta^\mu \equiv (1,\mathbf{0})$, $\mu$ (in the fraction $\mu/c$)is the magnetic permeability of the dielectric medium with the dielectric constant $\varepsilon$, $c$ is the velocity of light in vacuum, $n$ is the index of refraction of this medium, and $D_+(x-x')$ was derived by (Schwinger et al., 1976) in the following form:

$$D_+(x-x') = \frac{i}{4\pi^2 c}\int_0^\infty d\omega \frac{\sin\frac{n\omega}{c}|\mathbf{x}-\mathbf{x}'|}{|\mathbf{x}-\mathbf{x}'|}e^{-i\omega|t-t'|}. \tag{6}$$

Using formulas (2), (3), (5) and (6), we get for the power spectral formula the following expression (Schwinger et al., 1976) :

$$P(\omega,t) = -\frac{\omega}{4\pi^2}\frac{\mu}{n^2}\int d\mathbf{x}d\mathbf{x}'dt'\frac{\sin\frac{n\omega}{c}|\mathbf{x}-\mathbf{x}'|}{|\mathbf{x}-\mathbf{x}'|}\cos[\omega(t-t')]\times$$
$$\times\left\{\varrho(\mathbf{x},t)\varrho(\mathbf{x}',t') - \frac{n^2}{c^2}\mathbf{J}(\mathbf{x},t)\cdot\mathbf{J}(\mathbf{x}',t')\right\}. \tag{7}$$

## 11.2 The two-dimensional Vavilov-Cherenkov effect

Now, we apply the last formula to the situations of the two-dimensional dielectric medium. We derive here the power spectrum of photons generated by charged particle moving within the plane of the graphene-like structure with index of refraction n. However, we cannot immediately apply the formula (7) to the graphene-like 2D structures because the index of refraction $n$ is $n(x,y,z) = 1, z > 0$, $n(x,y,z) = const > 1, z = 0$ and $n(x,y,z) = 1, z < 0$. It means that the situation is not the Vavilov-Cherenkov problem but the problem with the transition radiation which was solved by Ginzburg and Tsytovich (1984) for thin dielectric film. The problem of the transition radiation when electron is moving with the arbitrary angle with respect to the boundary is discussed by Bass et al. (1965). Our goal is to solve only the Vavilov-Cherenkov radiation of charge when moving within the plane of dielectric sheet. So, it needs some modified approach.

While the graphene sheet is conductive, some graphene-like structures, for instance graphene with implanted ions, or, also 2D-glasses, are dielectric media, and it means that it enables the experimental realization of the Vavilov-Cherenkov radiation. Some graphene-like structure can be represented by graphene-based polaritonic crystal sheet (Bludov et al., 2012) which can be used to study the Vavilov-Cherenkov effect. We calculate it from the viewpoint of the Schwinger theory of sources (Schwinger, 1970).

The charge and current density of electron moving with the velocity $\mathbf{v}$ and charge $e$ is as it is well known:

$$\varrho = e\delta(\mathbf{x} - \mathbf{v}t) \tag{8}$$

$$\mathbf{J} = e\mathbf{v}\delta(\mathbf{x} - \mathbf{v}t). \tag{9}$$

In case of the the two-dimensional Vavilov-Cherenkov radiation by source theory formulation, the form of equations (2) and (3) is the same with the difference that $\eta^\mu \equiv (1, \mathbf{0})$ has two space components, or $\eta^\mu \equiv (1, 0, 0)$, and the Green function $D_+$ as the propagator must be determined by the two-dimensional procedure. In other words, the Fourier form of this propagator is with $(dk) = dk^0 d\mathbf{k} = dk^0 dk^1 dk^2 = dk^0 k dk d\theta$

$$D_+(x - x') = \int \frac{(dk)}{(2\pi)^3} \frac{1}{\mathbf{k}^2 - n^2(k)^2} e^{ik(x-x')}, \tag{10}$$

or, with $R = |\mathbf{x} - \mathbf{x}'|$

$$D_+(x - x') = \frac{1}{(2\pi)^3} \int_0^{2\pi} d\theta \int_0^\infty k dk \int_{-\infty}^\infty \frac{d\omega}{c} \frac{e^{ikR\cos\theta - i\omega(t-t')}}{k^2 - \frac{n^2\omega^2}{c^2} - i\varepsilon}. \tag{11}$$

Using $\exp(ikR\cos\theta) = \cos(kR\cos\theta) + i\sin(kR\cos\theta)$ and $(z = kR)$

$$\cos(z\cos\theta) = J_0(z) + 2\sum_{n=1}^\infty (-1)^n J_{2n}(z)\cos 2n\theta \tag{12}$$

and

$$\sin(z\cos\theta) = \sum_{n=1}^\infty (-1)^n J_{2n-1}(z)\cos(2n-1)\theta, \tag{13}$$

where $J_n(z)$ are the Bessel functions (Kuznetsov, 1962), we get after integration over $\theta$:

$$D_+(x - x') = \frac{1}{(2\pi)^2} \int_0^\infty k dk \int_{-\infty}^\infty \frac{d\omega}{c} \frac{J_0(kR)}{k^2 - \frac{n^2\omega^2}{c^2} - i\varepsilon} e^{-i\omega(t-t')}. \tag{14}$$

The $\omega$-integral in (14) can be performed using the residuum theorem after integration in the complex half $\omega$-plane.

The result of such integration is the propagator $D_+$ in the following form:

$$D_+(x - x') = \frac{i}{2\pi c} \int_0^\infty d\omega J_0\left(\frac{n\omega}{c}|\mathbf{x} - \mathbf{x}'|\right) e^{-i\omega|t-t'|}. \tag{15}$$

The spectral formula for the two-dimensional Vavilov-Cherenkov radiation is the analogue of the formula (7), or,

$$P(\omega,t) = -\frac{\omega}{2\pi}\frac{\mu}{n^2}\int d\mathbf{x}d\mathbf{x}'dt' J_0\left(\frac{n\omega}{c}|\mathbf{x}-\mathbf{x}'|\right)\cos[\omega(t-t')]\times$$

$$\times\left\{\varrho(\mathbf{x},t)\varrho(\mathbf{x}',t') - \frac{n^2}{c^2}\mathbf{J}(\mathbf{x},t)\cdot\mathbf{J}(\mathbf{x}',t')\right\}, \qquad (16)$$

where the charge density and current involves only two-dimensional velocities and integration is also only two-dimensional.

The difference is in the replacing mathematical formulas as follows:

$$\frac{\sin\frac{n\omega}{c}|\mathbf{x}-\mathbf{x}'|}{|\mathbf{x}-\mathbf{x}'|} \quad\longrightarrow\quad J_0\left(\frac{n\omega}{c}|\mathbf{x}-\mathbf{x}'|\right). \qquad (17)$$

So, After insertion the quantities (8) and (9) into (16), we get:

$$P(\omega,t) = \frac{e^2}{2\pi}\frac{\mu\omega v}{c^2}\left(1-\frac{1}{n^2\beta^2}\right)\int dt' J_0\left(\frac{nv\omega}{c}|t-t'|\right)\cos[\omega(t-t')], \quad \beta = v/c, \qquad (18)$$

where the $t'$-integration must be performed. Putting $\tau = t'-t$, we get the final formula:

$$P(\omega,t) = \frac{e^2}{2\pi}\frac{\mu\omega v}{c^2}\left(1-\frac{1}{n^2\beta^2}\right)\int_{-\infty}^{\infty} d\tau J_0\left(n\beta\omega\tau\right)\cos(\omega\tau), \quad \beta = v/c. \qquad (19)$$

The integral in formula (19) is involved in the tables of integrals (Gradshteyn et al., 1962). Or,

$$J = \int_0^{\infty} dx J_0\left(ax\right)\cos(bx) = \frac{1}{\sqrt{a^2-b^2}}, \quad 0<b<a,$$

$$J = \infty,\ a=b;\ J=0, \quad 0<a<b, \qquad (20)$$

In our case we have $a = n\beta\omega$ and $b = \omega$. So, the power spectrum in eq. (19) is as follows with $J_0(-z) = J_0(z)$:

$$P = \frac{e^2}{\pi}\frac{\mu v}{c^2}\left(1-\frac{1}{n^2\beta^2}\right)\frac{2}{\sqrt{n^2\beta^2-1}}, \quad n\beta>1,\ \beta = v/c. \qquad (21)$$

and

$$P = 0;\ n\beta<1, \qquad (22)$$

which means that the physical meaning of the quantity $P$ is really the Vavilov-Cherenkov radiation. And it is in our case the two-dimensional form of this radiation.

The fundamental features of the 3D and 2D Vavilov-Cherenkov radiation are as follows:
1) The radiation arises only for particle velocity greater than the velocity of light in the dielectric medium.
2) It depends only on the charge and not on mass of the moving particles
3) The radiation is produced in the visible interval of the light frequencies and partly in the ultraviolet part of the frequency spectrum. The radiation does not exists for very

short waves, which follows from the dispersion theory of the index of refraction $n$, where $n < 1$.

4) The spectral dependency on the frequency is linear for the 3D homogeneous medium.

5) The radiation generated in the 3D medium at given point of the trajectory spreads on the surface of the Mach cone with the vertex at this point and with the axis identical with the direction of motion of the particle. The vertex angle of the cone is given by the relation $\cos\Theta = c/nv$.

6) There is no Mach cone in the 2D dielectric medium. There is only the Mach angle in the 2D sheet. It follows from the fact that Vavilov-Cherenkov effect is the result of the collective motion of the 2D dielectric medium and it also follows from the quantum definition of the Vavilov-Cherenkov effect in the 2D structures. The conservation laws of momentum and energy for the Vavilov-Cherenkov effect is as follows:

$$\mathbf{p}_i = \mathbf{p}_f + \hbar\mathbf{k}, \tag{23}$$

$$E_i = E_f + \hbar\omega, \tag{24}$$

where index $i$ concerns the initial momentum and energy of an electron and index $f$ concerns the final momentum and energy of an electron. Symbol $\mathbf{k}$ is the wave vector of emitted photon and $\hbar\omega$ is its energy. With regard to the situation that the motion of an electron is realized in the plane $x-y$, the 3D Mach cone cannot be realized (The existence of Mach cone in our situation is the nonphysical escape of photons from 2D plane to the extra-dimension). So, the nonexistence of the Mach cone in the 2D structures is not mysterious.

While the formula for the three dimensional (3D) Vavilov-Cherenkov radiation is well known the from textbooks and monographs, the two-dimensional (2D) form of the Vavilov-Cherenkov radiation was derived here. Zuev (2009) considers the Vavilov-Cherenkov phenomenon in nanofilms from Au, Ag, Cu, where the Vavilov-Cherenkov phenomenon is realized only as the surface plasmons which cannot escape the 2D medium.

## 12 Velocity of sound in the black body photon sea

We determine the velocity of sound in the blackbody gas of photons. Derivation is based on the thermodynamic theory of the photon gas and the Einstein relation between energy and mass. The spectral form for the n-dimensional blackbody is derived. The 1D, 2D and 3D blackbody radiation is specified.

The spectral form of the blackbody radiation was derived firstly by Planck. The original Planck derivation of the blackbody radiation was based on the relation between the entropy of the system and the internal energy of the blackbody denoted by Planck as $U$.

While from the postulation of the relation

$$\frac{d^2S}{dU^2} = -\frac{const}{U} \tag{1}$$

the Wien law follows, the a priori generalization of eq. (1) gives new physics. The generalization of the equation (1) to be in harmony with blackbody thermodynamics was postulated by Planck in the following form:

$$\frac{d^2S}{dU^2} = -\frac{k}{U(\varepsilon + U)}, \tag{2}$$

where $\varepsilon$ has the dimensionality of energy, $k$ is the Boltzmann constant, and formula (2) is the approximation of the more general formula $d^2S/dU^2 = \alpha/\sum_n a_n U^n$ leading to exotic statistics.

The first integration of eq. (2) can be performed using the integral

$$\int \frac{dx}{x(a+bx)} = -\frac{1}{a}\ln\left|\frac{a}{x} + b\right|. \tag{3}$$

After integration we get the following result:

$$\frac{1}{T} = \frac{dS}{dU} = \frac{k}{\varepsilon}\ln\left(\frac{\varepsilon}{U} + 1\right). \tag{4}$$

The solution of eq. (4) is

$$U = \frac{\varepsilon}{\mathrm{e}^{\varepsilon/kT} - 1}. \tag{5}$$

The general validity of the Wien law

$$\frac{dS}{dU} = \frac{1}{\nu} f\left(\frac{U}{\nu}\right) \tag{6}$$

confronted with the equation (4) gives the famous Planck formula $\varepsilon = h\nu$.

The next step of Planck was to find the appropriate physical statistical system (heuristic model) which led to the correct power spectrum of the blackbody. This model was the thermal reservoir of the independent electromagnetic oscillators with the discrete energies $\varepsilon = h\nu$.

Einstein introduced coefficients of spontaneous and stimulated emission $A_{mn}, B_{mn}, B_{nm}$. In case of spontaneous emission, the excited atomic state decays without external stimulus as an analog of the natural radioactivity decay. Later, quantum theory explained rigorously the process of spontaneous emission. The energy of the emitted photon is given by the Bohr formula. In the process of the stimulated emission the atom is induced by the external stimulus to make the same transition. The external stimulus is a black body photon that has an energy given by the Bohr formula.

The Planck power spectral formula is as follows:

$$P(\omega)d\omega = \hbar\omega G(\omega)\frac{d\omega}{\exp\frac{\hbar\omega}{k_BT} - 1}; \quad G(\omega) = \frac{\omega^2}{\pi^2 c^3}, \tag{7}$$

where $\hbar\omega$ is the energy of a blackbody photon and $G(\omega)$ is the number of electromagnetic modes inside of the blackbody, $k$ is the Boltzmann constant, $c$ is the velocity of light, $T$ is the absolute temperature.

The internal density energy of the blackbody gas is given by integration of the last equation over all frequencies $\omega$, or

$$u = \int_0^\infty P(\omega)d\omega = aT^4; \quad a = \frac{\pi^2 k^4}{15\hbar^3 c^3}. \tag{8}$$

## 12.1 The speed of sound in the blackbody photon gas

In order to understand the the derivation of speed of sound in gas and in the relic photon sea, we start with the derivation of the speed of sound in the real elastic rod.

Let $A$ be the cross-section of the element $Adx$ of a rod, where $dx$ is the linear infinitesimal length on the abscissa $x$. The $\varphi(x,t)$ let be deflection of the element $Adx$ at point $x$ at time $t$. The shift of he element $Adx$ at point $x+dx$ is evidently

$$\varphi + \frac{\partial\varphi}{\partial x}dx. \tag{9}$$

The relative prolongation is evidently $\partial\varphi(x,t)/\partial x$ . The differential equation of motion of the rod can be derived by the following obligate way. We suppose that the force tension $F(x,t)$ acting on the element $Adx$ of the rod is given by the Hook law:

$$F(x,t) = EA\frac{\partial\varphi}{\partial x}, \tag{10}$$

where $E$ is the Young modulus of elasticity, $A$ is the cross section of the rod. We easily derive that

$$F(x+dx) - F(x) \approx EA\frac{\partial^2\varphi}{\partial x^2}dx \tag{11}$$

The mass of the element $Adx$ is $\varrho Adx$, where $\varrho$ is the mass density of the rod and the dynamical equilibrium is expressed by the Newton law of force:

$$\varrho Adx\varphi_{tt} = EA\varphi_{xx}dx \tag{12}$$

or,

$$\varphi_{tt} - v^2\varphi_{xx} = 0, \tag{13}$$

where

$$v = \left(\frac{E}{\varrho}\right)^{1/2} \tag{14}$$

is the velocity of sound in the rod.

The complete solution of eq. (13) includes the initial and boundary conditions. We suppose that the velocity law (14) involving modulus of elasticity and mass density is valid also for gas intercalated in the rigid cylinder tube. According to the definition of the Young modulus of elasticity where $(\Delta L/L)$ is the relative prolongation of a rod, we have as an analogue for the tube of gas $\Delta V/V$, $F \to \Delta p$, where $V$ is the volume of a gas and $p$ is pressure of a gas. Then, the modulus of elasticity is defined as the analogue of eq. (10). Or,

$$E = -\frac{dp}{dV}V. \tag{15}$$

The process of the sound spreading in ideal gas is the adiabatic thermodynamic process with no heat exchange. We use it later as a model of the sound spreading in the gas of blackbody photons. Such process is described by the thermodynamical equation

$$pV^\kappa = const, \tag{16}$$

where $\kappa$ is the Poisson constant defined as $\kappa = c_p/c_v$, with $c_p, c_v$ being the specific heat under constant pressure and under constant volume.

After differentiation of eq. (16) we get the following equation

$$dpV^{\kappa} + \kappa V^{\kappa-1}dV = 0, \tag{17}$$

or,

$$\frac{dp}{dV} = -\kappa\frac{p}{V}. \tag{18}$$

After inserting of eq. (18) into eq. (15), we get from eq. (14) for the velocity of sound in gas the so called Newton-Laplace formula:

$$v = \sqrt{\kappa\frac{p}{\varrho}}, \tag{19}$$

where $\varrho$ is the mass density of gas.

The density of the equilibrium radiation is given by the Stefan-Boltzmann formula

$$u = aT^4, ; \quad a = 7,5657.10^{-16}\frac{\mathrm{J}}{\mathrm{K^4m^3}}. \tag{20}$$

.

Then, with regard to the thermodynamic definition of the specific heat

$$c_v = \left(\frac{\partial u}{\partial T}\right)_V = 4aT^3. \tag{21}$$

Similarly, with regard to the general thermodynamic theory

$$c_p = c_v + \left[\left(\frac{\partial u}{\partial V}\right)_T + p\right]\left(\frac{\partial V}{\partial T}\right)_p = c_v, \tag{22}$$

because $\left(\frac{\partial V}{\partial T}\right)_T = 0$ for photon gas and in such a way, $\kappa = 1$ for photon gas. According to the theory of relativity, there is simple equivalence between mass and energy. Namely, $m = E/c^2$. At the same time, there is relation between pressure and the internal energy of the blackbody gas following from the electromagnetic theory of light $p = u/3$. So, in our case

$$\varrho = u/c^2 = \frac{aT^4}{c^2}; \quad p = \frac{u}{3}. \tag{23}$$

So, after insertion of formulas in equation (23) in to eq. (19), we get the final formula for the velocity of sound in three photon sea of the blackbody is as follows:

$$v = c\sqrt{\frac{\kappa}{3}} = \frac{c}{3}\sqrt{3}, \tag{24}$$

which is the result derived by Partovi (1994) using the QED theory applied to the photon gas. No energy signal can move with velocity greater than the speed of light. And we correctly derived $v/c < 1$.

So, we have seen in this section, that using the classical thermodynamical model of sound in the classical gas we can easily derive some properties of the black body gas, namely the velocity of sound in it and in the relic photon sea. It is not excluded that the relic sound can be detected by the special microphones of Bell laboratories. Let us still remark that if we use van der Waals equation of state, or, the Kamerlingh Onnes virial equation of state, the obtained results will be modified with regard to the basic results.

## 12.2 The n-dimensional blackbody

The problem of the n-dimensional blackbody is related to the dimensionality of space and some ideas on the dimensionality of space was also discussed by many authors. The experimental facts following from QED experiments, galaxy formation and formation of the molecules DNA, prove that the external space is 3-dimensional. With regard to the Russell philosophy of mathematics, there is no possibility to prove the dimensionality of space, or, space-time, by means of pure mathematics, because the statements of mathematics are non-existential. The existence of the external world cannot be also proved by pure mathematics. However, if there is an axiomatic system related adequately to the external world and reflecting correctly the external world, then, it is possible to do many predictions in the external world by pure logic. This is the substance of exact sciences.

In case of the n-dimensional blackbody, the number of modes can be determined (Al-Jaber, 2003). We use here alternative and elementary derivation. In case we consider instead of the three-dimensional blackbody the n-dimensional blackbody, the photon energy is defined by the same manner and at the same time the statistical factor is the same as in the three-dimensional case. Only number of the electromagnetic modes $G(\omega)$ depends on dimensionality of space. We determine in this article the Planck blackbody law for the n-dimensional space..

The blackbody radiation is composed from the electromagnetic waves corresponding to photons in such a way that every monochromatic wave is of the form:$A_\mu = \varepsilon_\mu e^{i\mathbf{kx}-i\omega t}$, where $\varepsilon_\mu$ is the polarization amplitude. If we take the blackbody in the form of cube with side $L$, then it is necessary to apply for the electromagnetic wave the boundary conditions. It is well known that the appropriate boundary conditions are so called periodic condition, which means for instance for x-coordinate $\exp(ik_1 0) = \exp(ik_1 L) = 1$, from which follows that only specific values of $k_1$ correspond to the boundary conditions, namely, $k_1 = \frac{2\pi N_1}{L}; \quad N_1 = 1, 2, 3...$ . In case that the electromagnetic field is in a box of the volume $L^n$, the wave vector $\mathbf{k}$ is quantized and the elementary volume in the k-space is

$$\Delta_{0n} = (2\pi)^n / L^n \tag{25}$$

.

The elementary volume of the n-dimensional k-space is evidently the volume $dV_n$ between spheres with radius $k$ and $k + dk$ (Rumer et al., 1977):

$$dV_n = d\left(\frac{2\pi^{n/2}}{n\Gamma\left(\frac{n}{2}\right)}k^n\right) = \frac{2\pi^{n/2}}{\Gamma\left(\frac{n}{2}\right)}k^{n-1}dk, \tag{26}$$

where $\Gamma(n)$ is so called Euler gamma-function defined in the internet mathematics ($http://mathworld.wolfram.com/GammaFunction.html$) as

$$\Gamma(x) = \int_0^\infty e^{-t} t^{x-1} dt; \quad \Gamma(n/2) = \frac{(n-2)!!\sqrt{\pi}}{2^{(n-1)/2}}. \tag{27}$$

The number of electromagnetic modes involved inside the spheres between $k$ and $k+dk$ is then, with $\omega = ck$, or $k = \omega/c$ and $dk = d\omega/c$,

$$G_n(\omega)d\omega = 2 \times \frac{dV_n}{\Delta_{0n}} = 2 \times \frac{1}{2^{(n-1)}} \frac{1}{\Gamma\left(\frac{n}{2}\right)} \frac{1}{\pi^{n/2}} L^n \frac{\omega^{n-1}}{c^n} d\omega, \tag{28}$$

where isolated number 2 expresses the fact that light has 2 polarizations.

For the energetic spectrum of the Planck law of the n-dimensional black body we have

$$P_n(\omega) = \hbar\omega G_n(\omega) \frac{1}{\exp(\frac{\hbar\omega}{kT}) - 1} = 2 \times \frac{1}{2^{(n-1)}} \frac{1}{\Gamma\left(\frac{n}{2}\right)} \frac{1}{\pi^{n/2}} \hbar \frac{\omega^n}{c^n} \frac{1}{\exp(\frac{\hbar\omega}{kT}) - 1}. \tag{29}$$

The energy density of the radiation of the n-dimensional blackbody is then

$$u_n = \int_0^\infty P_n(\omega) d\omega = A_n \int_0^\infty \frac{\omega^n}{\exp(\frac{\hbar\omega}{kT}) - 1} d\omega; \quad A_n = \frac{1}{2^{(n-1)}} \frac{2\hbar}{c^n \pi^{n/2}} \frac{1}{\Gamma\left(\frac{n}{2}\right)}. \tag{30}$$

The integral in the last formula can be evaluated using well-known relations (Dwight, 1961) (int. 860.39)

$$\int_0^\infty \frac{x^p}{e^{ax} - 1} dx = \frac{\Gamma(p+1)\zeta(p+1)}{a^{p+1}} = \frac{p!\zeta(p+1)}{a^{p+1}} = \frac{p!}{a^{p+1}} \left[1 + \frac{1}{2^{p+1}} + \frac{1}{3^{p+1}} + \ldots\right], \tag{31}$$

where $\zeta(p)$ is so called Riemann $\zeta$-function and $a = \hbar/kT$.

Let us test the n-dimensional Planck law and density radiation in case of n = 1, 2, and 3.

$$P_1(\omega) = 2 \times \frac{1}{\Gamma(1/2)} \frac{1}{\sqrt{\pi}} \frac{\hbar\omega}{e^{(\frac{\hbar\omega}{kT})} - 1} \frac{1}{c} \tag{32}$$

$$P_2(\omega) = 2 \times \frac{1}{2} \frac{1}{\Gamma(2/2)} \frac{1}{\pi} \frac{\hbar\omega^2}{e^{(\frac{\hbar\omega}{kT})} - 1} \frac{1}{c^2} \tag{33}$$

$$P_3(\omega) = 2 \times \frac{1}{4} \frac{1}{\Gamma(3/2)} \frac{1}{\pi^{3/2}} \frac{\hbar\omega^3}{e^{(\frac{\hbar\omega}{kT})} - 1} \frac{1}{c^3}, \tag{34}$$

and so on.

Let us remark, that $P_1$ corresponds to the radiation of 1D blackbody and can be verified by long carbon nanotube at temperature $T$. $P_2$ corresponds to the radiation of 2D blackbody and can be verified by the graphene sheet (Pardy, 2007b, 2010, 2011) after some geometrical modification. $P_4$ and further formulas cannot be realized in the 3D space with the adequate blackbody.

$$u_1 = A_1 \int_0^\infty \frac{x}{e^{ax} - 1} dx = A_1 \left(\frac{kT}{\hbar}\right)^2 1!\zeta(2) = A_1 \left(\frac{kT}{\hbar}\right)^2 \frac{\pi^2}{6}; \quad A_1 = \frac{2\hbar}{c\pi^{1/2}} \frac{1}{\Gamma\left(\frac{1}{2}\right)} \tag{35}$$

$$u_2 = A_2 \int_0^\infty \frac{x^2}{e^{ax}-1}dx = A_2 \left(\frac{kT}{\hbar}\right)^3 2!\zeta(3) = A_2 \left(\frac{kT}{\hbar}\right)^3 2,4..; \quad A_2 = \frac{\hbar}{c^2\pi}\frac{1}{\Gamma(1)} \quad (36)$$

$$u_3 = A_3 \int_0^\infty \frac{x^3}{e^{ax}-1}dx = A_3 \left(\frac{kT}{\hbar}\right)^4 3!\zeta(4) = A_3 \left(\frac{kT}{\hbar}\right)^4 6\frac{\pi^4}{90}; A_3 = \frac{\hbar}{2c^3\pi^{3/2}}\frac{1}{\Gamma\left(\frac{3}{2}\right)} \quad (37)$$

and so on, where we used tables of Dwight (1961) with formulas 48.002, 48.003, 48.004 for $\zeta(2) = \pi^2/6, \zeta(3) = 1,2020569032, \zeta(4) = \pi^4/90$

Let us remark that the formula (37) is identical with formula (8) with regard to relation $\Gamma(x+1) = x\Gamma(x)$, or, $\Gamma(3/2) = \Gamma(1/2+1) = (1/2)\Gamma(1/2) = (1/2)\pi^{1/2}$, and it is the proof of the correctness of derived formula $u_3$.

We have seen that our derivation of the light velocity in the blackbody photon gas was based on the classical thermodynamical model with the adiabatic process ($\delta Q = 0$), controlling the spreading of sound in the gas. The problem was not solved by Einstein, because only QED, elaborated many years later was able to give motivation for the formulation of such problem. In other words, Einstein was not motivated for such activity. Partovi (1994) derived additional radiation corrections to the Planck distribution formula and the additional correction to the speed of sound in the relic photon sea. His formula is of the form:

$$v_{sound} = \left[1 - \frac{88\pi^2\alpha^2}{2025}\left(\frac{T}{T_e}\right)^4\right]\frac{c}{\sqrt{3}}, \quad (38)$$

where $\alpha$ is the fine structure constant and $T_e = 5.9$ G Kelvin. We see that our formula is the first approximation in the Partovi expression.

There is rigorous statistical theory of transport of sound energy in gas based on the Boltzmann equation (Uhlenbeck et al., 1963 ). After application of Boltzmann equation to the photon gas, or, relic photon gas we can expect the rigorous results with regard to fact that the cross-section of the photon-photon interaction is very small. Namely, (Berestetzky et al., 1989):

$$\sigma_{\gamma\gamma} = 4,7\alpha^4\left(\frac{c}{\omega}\right)^2; \quad \hbar\omega \ll mc^2, \quad (39)$$

and

$$\sigma_{\gamma\gamma} = \frac{973}{10125\pi}\alpha^2 r_e^2\left(\frac{\hbar\omega}{mc^2}\right)^6; \quad \hbar\omega \gg mc^2, \quad (40)$$

where $r_e = e^2/mc^2 = 2,818 \times 10^{-13}$ cm is the classical radius of electron and $\alpha = e^2/\hbar c$ is the fine structure constant with numerical value $1/\alpha = 137,04$.

No doubt, the solution of the Boltzmann equation gives the existence of sound waves in the statistical system of particles.

## 13 Conclusion

We have considered a quantum phenomenon in which electrons are emitted from matter after the absorption of energy from electromagnetic radiation. Or, in other words, we discussed so called the photoelectric effect.

We have considered the classical theory of photoeffect and its extension to the nonrelativistic and relativistic quantum theory of photoeffect in the form of ionization of atoms. We have investigated the problems concerning the photoelectric effect including phonon generation and process with the initial dressed photon. We have considered also the polychromatic form of the photoeffect and the photoeffect in two-dimensional electron gas in magnetic field. As the related problem, we have calculated the H-atom in the black body sea, being related to the Gibbons-Hawking thermal bath. The related problems such as the velocity of sound in the relic photon sea, thermal Casimir effect, dielectric crystal immersed in the black-body sea and the Cherenkov radiation in the two-dimensional dielectric medium were included.

The dressed photon is here considered as the photon composed from the electron-positron pair.

The H-aton imersed in the black-body photon sea is related problem to photoeffect. Such a case is an analogue of the H-atom in the Gibbons-Hawking thermal bath and it has the astrophysical meaning (Pardy, 2016a).

The dielectric crystal immersed in the black-body is equivalent to the influence of the index of refraction on the spectral formula of the blackbody (Pardy, 2015).

The Casimir effect at temperature finite temperature is the old problem and our approach was original.

The Cherenkov radiation in the two-dimensional dielectric medium (Pardy, 2015b) is the original problem.

The calculation of the velocity of sound in the relic photon sea which is the relic astrophysical black-body (Pardy, 2013a,b) is of the astrophysical meaning.

Zuev (2009) considers the Vavilov-Cherenkov phenomenon in nanofilms from Au, Ag, Cu, where the Vavilov-Cherenkov phenomenon is realized only as the surface plasmons which cannot escape from the 2D medium. The fundamental importance of the Vavilov-Cherenkov radiation is in its use for the modern detectors of very speed charged particles in the high energy physics. The detection of the Vavilov-Cherenkov radiation enables to detect not only the existence of the particle, however, also its direction of motion and its velocity and also its charge. The two-dimensional Vavilov-Cherenkov radiation is the promising application in LED, the light-emitting diode.

The light-emitting diode, LED, consists of several layers (sheets) of semiconducting materials. The Nobel prize laureates, Isamu Akasaki (Nagoya University, Japan), Hiroshi Amano (Nagoya University, Japan), Huji Nakamura (American citizen, University of California, Santa Barbara, USA) succeeded in increasing the lamps efficiency (Royal Swedish Academy of Sciences, 2014); . White LEDs currently reach more than 300 lm/W, representing more than 50% wallplug efficiency.

The relation of the Vavilov-Cherenkov effect to LED is evident. Namely, when LED (with additional dielectric sheet) is irradiated by high-energy electrons with velocity greater than the velocity of light in the sheet, then LED produces the 2D Vavilov-Cherenkov radiation if and only if the electrons move within the dielectric sheet inside the LED. The set of small grain-sand LED (fixed in adequate viscous gel emulsion) forms then the new detector of elementary particle physics. The two-dimensional Vavilov-Cherenkov radiation was still not applied, nevertheless, it is not excluded that it is the crucial effect in LED.

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# INVESTIGATION OF THE KINETICS OF FERMENTATION OF PUMPKIN PULP

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***Abstract***

The problem of processing pumpkin pulp with the further introduction of appropriate technological solutions was studied. The influence of temperature, time, heat treatment of pumpkin pulp and the concentration of the introduced enzyme preparation on the dynamics of accumulation of pectin is investigated in the article. The directed action of Vetom 1.1 based on an enzyme produced by bacteria of the genus Bacillus subtilis was studied. It is proved that the rational conditions of the process are t=55˚C, τ=15 hours, 7,5% of the enzyme preparation to the mashed pulp of pumpkin pulp. Taking into account the obtained data, a conclusion was reached on the effectiveness of using fermented mashed pumpkin pulp in food technology.

**Key words:**

pumpkin pulp, temperature, time fermentation, microbial origin enzyme, pectin

## Introduction

Pumpkin is considered one of the oldest melon cultures. The genus Cucurbita includes five cultivated and sixteen wild-types of pumpkins. Almost cultural species in Ukraine, the most common are three species: large-frblited pumpkin or Greek - Cucurbita Duch Tahiti., Pumpkin hard-boiled (ordinary or table-top) - Cucurbita retro L., Muscat pumpkin - CucurbitamoschataDuch. Each of these species has its own peculiarities.

The areas of pumpkin cultivation in the industrial sector of vegetable growing (agricultural organizations and farms, excluding farm households) in Ukraine over the past 15 years have grown more than 3 times and make to 744,4 thousand tons for a total area of 25 thousand hectares. Pumpkin grows in Kherson, Zaporozhye, Donetsk, Mykolayiv, Odessa regions. Here are formed the most favorable soil and climatic conditions for their cultivation [1].

The cultivation of pumpkins in Ukraine is carried out in order to their further industrial processing for the production of oil and shredded pumpkin seeds. Pulp, after takingseeds, is used for livestock feed and for silage. In general, only 28% of the total amount of pulp pumpkin is sent for further processing [2]. While fetal pulp of this melon culture contains sugars, pectin, potassium salts, calcium, magnesium, iron, vitamins C, $B_1$, $B_2$, $B_6$, $B_9$, PP and provitamin A. A small amount of fiber (0,7% ) and organic acids can include pumpkin in a diet with diseases of the gastrointestinal tract, and a large amount of pectin has a particularly positive effect on inflammation of the large intestine. Since pectin promotes excretion of cholesterol, the pumpkin is very useful in atherosclerosis. Fresh pumpkin pulp improves bowel function. Pumpkin also has a diuretic effect that can be used in dietary nutrition with edema associated with cardiovascular disease, and some diseases of the kidneys and bladder. There is an ability of pectin substances to remove toxic substances and radioactive metals from the body [3].

Thus, taking into account the above nientioned, and in accordance with the "Declaration on Low-and and Non-Waste Technologies", it is necessary tostudy of the problem of processing pumpkin pulp with the further introduction of appropriate technological solutions [4]. S.O. Belinskaya, N.Ya. Orlov, AM Odarchenko, E.V. Bayludova, V.M. Golubev, V.Yu. Michalov, AV Matora, O.G. Shkodina, V.E. Korshunova, V.F. Vinnitsa, MM Tipzyna, GK Seleznev and others were engaged in food processing of pumpkin .

Among the now known methods for processing pulp of pumpkin is a method of complex processing, which involves its preparation, cutting, seed removal, blanching of pulp, its wiping and homogenization with the receipt of juice. Pumpkin juice obtained from the described technology is not in high demand due to the specific smell of boiled pumpkin.

Among the industrial methods of processing pulp of pumpkin Odarnenko O.M. patented method of producing pasta based on pumpkin and carrots, which involves the preparation of reciped components, purification and grinding of vegetables, cooking containing a spicy aromatic herbs and citric acid, wiping, mixing with reciped components, homogenizing, evaporating, followed by xanthan, re-homogenization, packing and canning. MalyukL.P. and Fetysova G.V. offer a method of making vegetable pasta from pumpkin and aronia for the processing of significant volumes of pumpkin pulp. Patented methods of production are characterized by a complex multi-stage technological process, which make the technology inadequate for implementation.

Pastushenko GV, Stoyanova O.V., Zubkova KV, Sidorchyk A.O. offer a way of preserving bits of hot puddings from pumpkin using spicy aromatic raw materials to produce pumpkin-coconut jam. Homogenized pulp is offered to preserve with the use of organic acids as preservatives by Zheplinska MM, Sheshlyuk O.S. The disadvantage of the famous recipe is an intense smell of boiled pumpkin. Boyko MM offers a way of processing pumpkins by making pumpkin-orange confectionery from pumpkin and apples with orange peanuts, which is distinguished by the fact that it has a pleasant citrus flavor, but has a high cost. For the same reason, Kuzmenko I.O. and Orlova Ya.A. offer a method of production of pumpkin apple quinced canned goods with improved consumer properties, which are characterized by complexity of technological processing.

There are ways of processing pumpkins to produce canned foods of other dishes with vegetable supplements that have unsatisfactory organoleptic properties, and fruit canning and vegetable raw materials by freezing or drying with the formation of pumpkin powder in accordance with TU U 15.3-05417118.024-2002 "Vegetable powder from carrots, beet-roots, potatoes, cabbage, pumpkin, zucchini, onion, garlic, spinach, rhubarb, and white roots of parsley, celery, parsnip "obtained by convection-vacuum drying (mass fraction of moisture 6 ... 8%).

Among the methods of processing pumpkin pulp at non-industrial scale plants, that is, at restaurants, preserving by freezing, the production of pastes, creams and dough semi-finished products with pulp of pumpkin are used. Dessert of pumpkin-dyed frozen was patented by Belinsky S.O. and Orlova N.Ya., pumpkin pie "Sonechko" and "Berlin miracle" with filling on the basis of pumpkin paste by Antonenko A.V., custard made from pumpkin and artichoke by Lewandowski L.V. etc. [5].

It is widely known the use of pumpkin pulp as a source of pectin, as a component of culinary and confectionery dishes. However, known technologies provide the use of temperature processing of pulp at pH=4, which is achieved by the addition of organic acids, which affects the taste of products and causes a great amount of sweeteners. In this regard, the search of optimal parameters for the processing of pulp pumpkin in order to obtain a universal semi-finished product with high content of the pectin for the use in confectionery and culinary products is relevant.

One of the effective ways to solve the problem with the preservation of biologically active substances of plant material is the use of enzyme preparations (AF), as well as the cultivation of microorganisms. Treating pumpkin with enzyme preparations increases the amount of pectin.

O.A. Markina, AV Matora, O.G. Shkodina, V.E. Korshunova were engaged in The problem of enzymatic processing of pulp of pumpkin. The application of enzymes produced by microorganisms of the genus Bacillus. According to these scientists, can increase the yield of pectin by 30-35% while preserving the environmental quality of the process of its obtaining. A known technical solution is a method for producing pectin consisting of cultivating Bacillus species on the substrate of microorganisms, further mixing the hydrolyzate with vegetable pectin containing material, extracting the mixture and isolating the soluble pectin. At the same time, despite the high degree of environmental friendliness of the process, it is advisable to ferment the plant material without removing pectin from its composition, and subsequently using it as a product with high content of pectin [6].

Thus, the way of recycling of secondary raw materials is promising in order to obtain a product based on pumpkin with a high content of pectin.

The purpose of this article is to investigate the kinetics of enzymolysis of pectin substances under the action of the enzyme preparation Vetom 1.1 depending on the influence of technological factors.

## Materials and methods

For the study was selected muscat pumpkin - Cucurbita moschata Duch. The Butternut variety, which is widely usedin the trading network and has excellent organoleptic qualities, and large-flowered or Greek pumpkin - Cucurbita Duch Tahiti. Ukrainian multibread variety, grown for the purpose of obtaining seeds and pumpkin oil.

The following temperature storage regimes have been applied to pumpkin samples: +8…+10˚C and -16…-18˚C.

The research was conducted for 10 months after the harvest of 2016.

Samples of pumpkin puree were subjected to the directed action of Vetom 1.1 based on an enzyme produced by bacteria of the genus Bacillus subtilis. The introduction of an enzyme preparation, which exists in the form of a powder, was carried out by dissolving it in a liquid fraction, separated unilaterally in the preparation of mashed pumpkin, followed by the connection of liquid and solid fractions.

The content of soluble pectin in the experimental samples was determined by the standard calcium-pectate method [7]. Statistical and mathematical methods of data processing were used to process the results of experimental studies.

## Results and discussion

The samples of mashed pumpkin pulp, which were subjected to enzyme treatment, were studied. The grinding of heat-treated pulp of pumpkin with the formation of mashed pumpkin having homogeneity of the consistence is due to the fact that pectin substances are localized in different parts of the fruit unevenly.

The technological process of obtaining puree from pumpkin with high content of pectin involves a number of technological steps: inspection, washing and cleaning, cutting with a cube with a rib size $(0,8\ldots1)\cdot10^{-2}$m, followed by thermal steam treatment at a temperature of 110±2˚C during $(20\ldots25)\cdot60$s, followed by grinding at a temperature of 80±2˚C and followed by heat treatment at a temperature of 75±5˚C for $(6\ldots7)\cdot60$c [8].

Activity of the preparation on the basis of the enzyme produced by the bacteria of the genus Bacillusubtilis, according to A. A. Matori, A. Shkodina, A. V. Korshunova. and Ptichkina N.M. is the maximum pH value of the medium approaching pH=7,5 [6]. At the same time, in her studies Yudina TI, the technology of temperature processing of pumpkin pulp which is based on our studies, recommends the introduction of citric acid for acidification of the medium in order to intensify the process of transition of protopectin to soluble pectin (RP) [8] . According to the fact that in the acidic environment the action of the enzyme preparation Vetom 1.1 is inhibited, then the citric acid was not introduced in the mashed pumpkin from the pulp of the pumpkin, maintaining a neutral or slightly alkaline pH medium.

The variability of the parameters of obtaining a product with high content of pectin determined the need to study the kinetics of fermentolysis, depending on the duration and temperature regime, the amount of enzyme preparation Vetom 1.1, from the pomological variety of pumpkin and from the temperature regimes of its storage.

Thus, in the process of storing pumpkin fruits of various sorts, the total amount of pectin substances is significantly reduced from the initial content at different storage temperatures. The undamaged fruit of the pumpkin is usually stored at +8...+10˚C, while the fruits with broken integrity of the outer shell are kept at -18...-16˚C. Thus, freezing contributes to a better preservation of food and biologically active substances and the uninterrupted supply of restaurant facilities with raw materials in comparison with traditional ways of preserving the pumpkin with whole fruits, which is economically unprofitable due to the need to keep fruit at constant temperature in the warehouse, and in the form segments in the treezers, which is inappropriate due to relatively short storage periods [9]. That is why it is relevant to study the process of fermentolysis in samples of pumpkin, which were kept at -18...-16˚C and at +8...+10˚C.

Thus, as the dynamics of the change in the total amount of pectin substances in the pumpkin fruit of the studied pomological grades varies in different temperature regimes, the content of RP (%) was determined depending on this indicator. The results of the studies are presented in Table 1.

*Table 1*

**Total content of pectin substances in different storage modes**

| Grade | Time Analysis | Storage mode | |
|---|---|---|---|
| | | +8…+10˚C | -18…-16˚C |
| Pumpkin nutmeg Butternut | October<br>March | 1,06<br>1,29 | 0,81<br>0,79 |
| Large-fruited pumpkin variety Ukrainian multi-breeding | October<br>March | 1,07<br>1,15 | 0,79<br>0,78 |

As we can see from the table, the quantitative changes in the content of pectin substances in the pumpkin fruit are characteristic of both botanical varieties. During the storage period, the amount of pectin increases at a temperature storage temperature of +8…+10˚C, which is accompanied by the transfer of protopectin into the form of soluble pectin. At the same time, at low temperature storage, pectin passed into a solution of intercellular fluid and was removed in the process of defrosting. Thus, samples of pumpkin pulp, which were to be stored at low temperatures, had a lower content of pectin substances by 40-47% than when stored at +8…+10˚C.

In addition, it can be seen from Table 1, the quantitative content of pectin substances also depends on the variety of pumpkin. In this regard, for the study the were selected, samples of the most popular varieties of pumpkin: dinnerware Batternat (Butternut) and breeding Ukrainian variety fertilizer [10].

In connection with the above mentioned, in the first stage of the study, the effect of the enzyme preparation was directed to experimental samples of pumpkin, which were stored at +8…+10˚C and -18...-16˚C (Fig. 1).

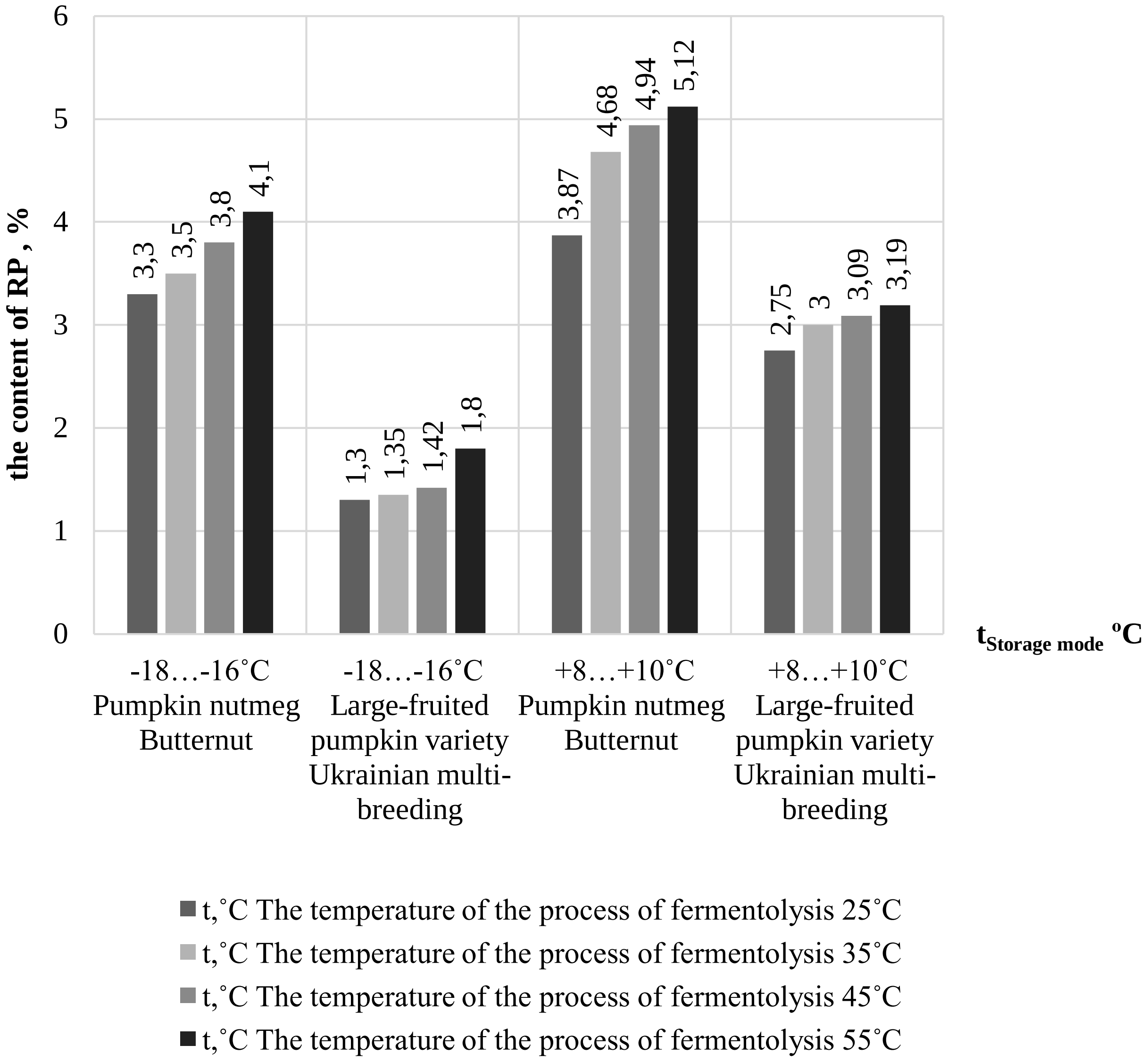


**Fig.1The kinetics of formation of RP (%) depending on storage (ºC)**

According to the results of the conducted researches (fig.1) it was proved, that the content of soluble pectin (RP) is increased unevenly in the same samples of pumpkin at different temperature storage parameters. This phenomenon is typical for both the table variety of pumpkin and forage. So, for a pumpkin variety, the Ukrainian large-fruit plant has an increase in the content of RP by 70% when stored at temperatures +8…+10˚C compared with the results obtained for long-term storage at -18...-16˚C. Similarly, an increase in the content of RP by 25% in samples of pumpkin of the Batternat variety was observed at temperatures +8...+10˚C in comparison with the temperature regime -

18...-16˚C. The resulting content of soluble pectin in the experimental samples varies depending on the variety in 1,3-2,5 times.

The next stage of the study was to establish an optimal temperature regime for the process of fermentolysis. During the study, the samples were thermoformed in cabinets with a constant temperature of 25˚C, 35˚C, 45˚C and 55˚C. These temperature regimes are selected taking into account the recommended values of the activity temperature of the enzyme produced by bacteria of the genus Bacillus tubilum [6].

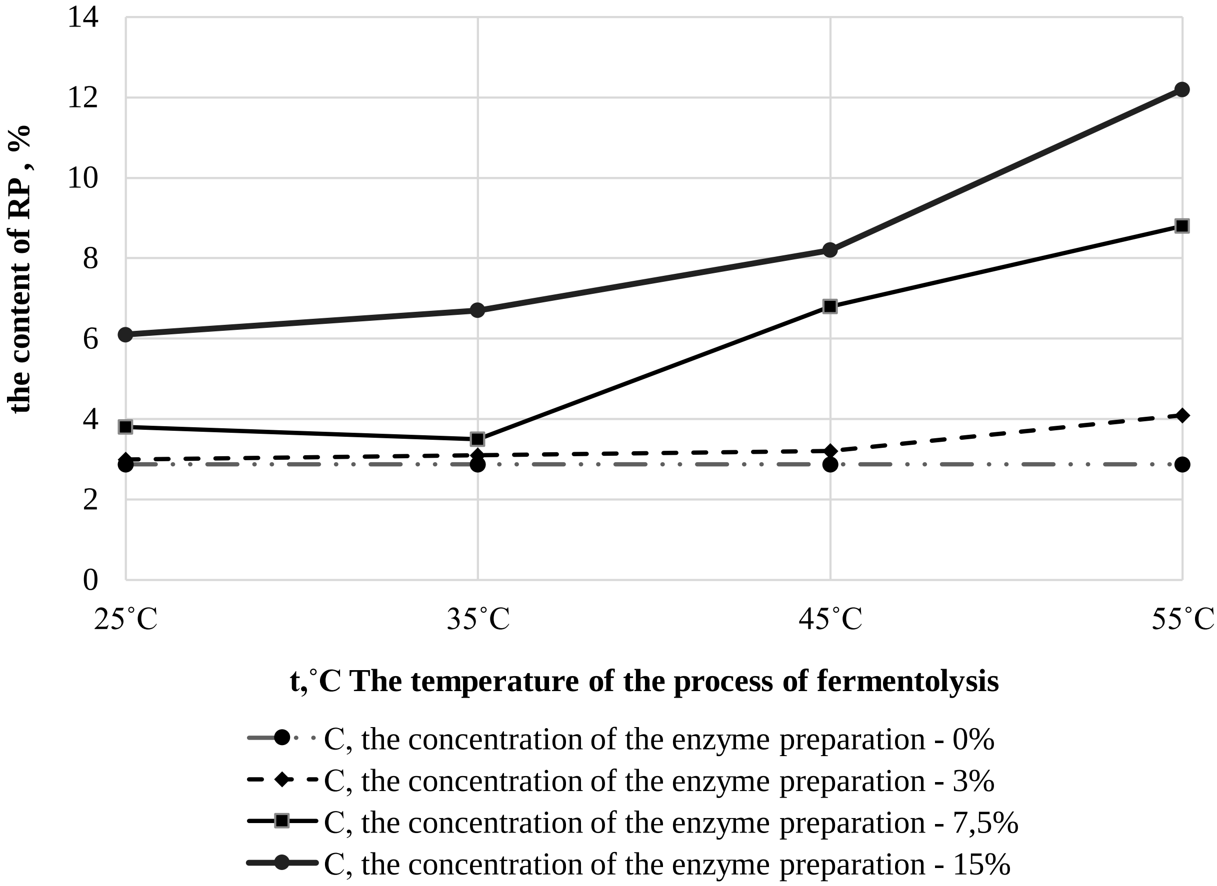


**Fig.2 The kinetics of formation of RP (%) depending on the temperature of the process of fermentolysis (t, ºC)**

From Fig. 2 it is evident that the temperature indices directly influence the process of fermentolysis. Thus, at a temperature of 55°C, the initial product contains the highest amount of RP (%) for all concentrations of the prepared Vetom 1.1. Since the growth of the concentration of soluble pectin is characteristic for all samples of both varieties of pumpkin and all concentrations of the enzyme used, for a greater clarity, the results of the study are taken from one type of process in the dynamics of temperature changes.

In addition, the samples with fermentation process was at a temperature of 55°C, were characterized by excellent organoleptic characteristics, in particular, the color and homogeneity of the consistency (Table 2).

*Table 2*

**Organoleptic characteristics**

| Sort | Temperature mode | | | |
|---|---|---|---|---|
| | **25 ºC** | **35 ºC** | **45 ºC** | **55 ºC** |
| pumpkin Muscat Butternut (Butternut) | The consistency is not homogeneous, with pronounced separation of dispersed phases, the pronounced aroma of pumpkin | Consistency is not homogeneous, with pronounced separation of dispersed phases, bright orange color, pronounced aroma of pumpkin | Consistency is homogeneous, bright orange, light pumpkin aroma. | Consistency is homogeneous, tender, bright orange, light pumpkin aroma. |
| Ukrainian pumpkin large-fruited variety | | | | |

The homogeneity of the purée consistency is explained by the high emulsifying capacity of pectin substances belonging to the group of low and medium-eutrophy. The stability of the formed emulsions is due to the mechanical strength of the interphase adsorption layer, which does not collapse as a result of heat treatment. Therefore, it is projected that organoleptic parameters will improve with increasing content of soluble pectin as a result of enzymatic treatment of mashed pumpkin. Therefore, it is necessary to follow the dependence of an increase in the percentage of content of pectin substances depending on the introduced concentration of the enzyme preparation (Fig. 3).

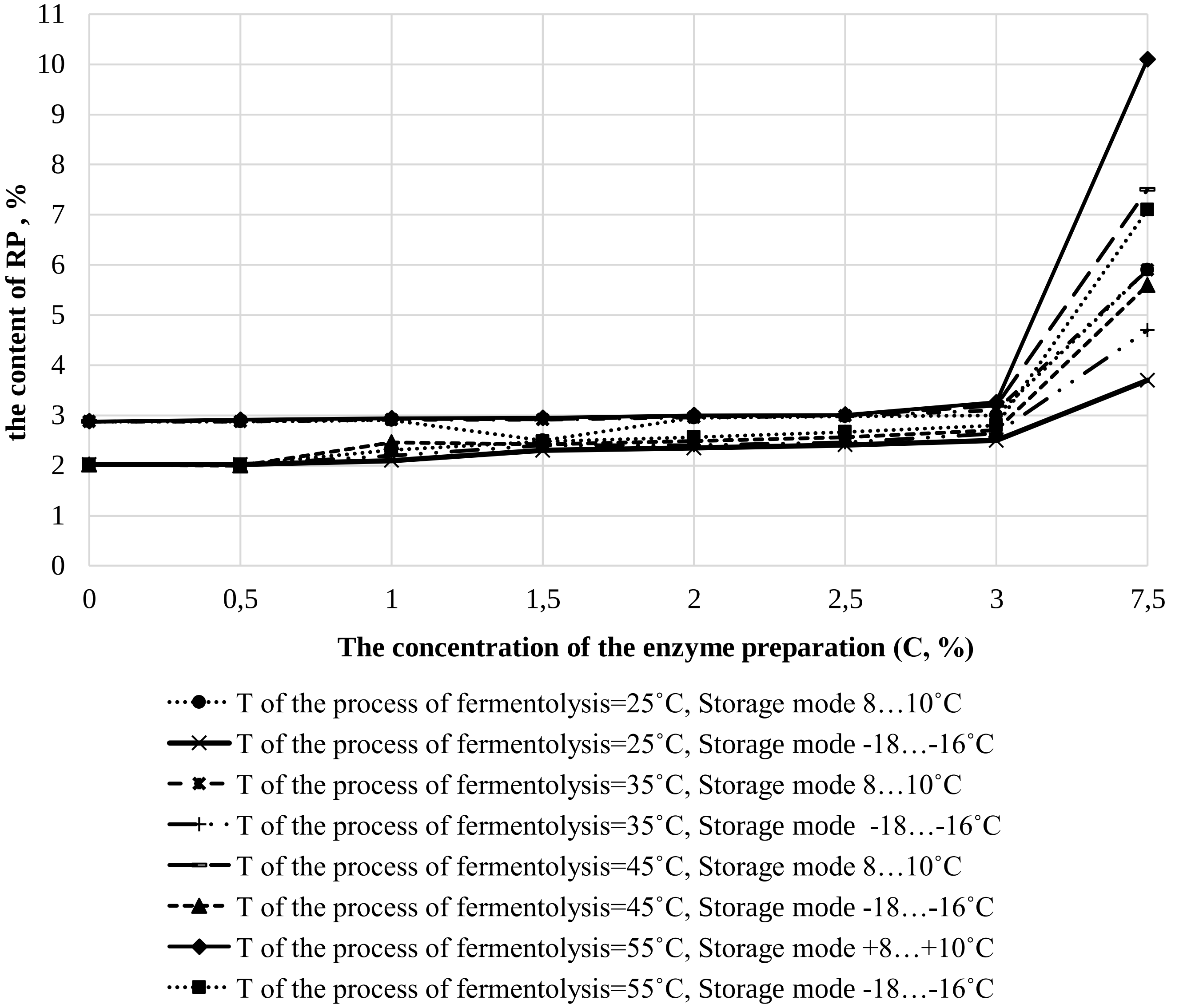


**Fig. 3 The kinetics of formation of RP (%) depending on the concentration of enzyme preparation (C,%)**

As can be seen from Fig. 3, a significant increase in the content of soluble pectin is observed when the concentration of the enzyme preparation is more than 3%. The use of an enzyme preparation in an amount less than 3% is inappropriate, in connection with the equalization of the benefits of reducing the cost of purchasing an enzyme preparation due to a significant increase in labor intensity, duration, energy efficiency of the process. On the other hand, taking into account the economic index, it is inappropriate to use the enzyme preparation in the amount of 15%, which leads to a significant increase in the cost of the original product with a slight increase in the content of soluble pectin compared with samples with a concentration of 7,5% of the enzyme preparation.

In order to determine the optimal duration of the process of fermentolysis, the change in the content of soluble pectin from the time process of fermentation was in vestigated (Fig. 4). So, Matora AV, Shkodina O.G., Korshunova V.E. and Ptichkina NM, the development of which is concerned with increasing the completeness of the yield of purified pectin from plant material in mild conditions, has established that the maximum amount of soluble pectin is observed during 15 hours. Therefore, it is advisable to investigate the effect of the formation of soluble pectinous pulp from pumpkin pulp as a result of treatment with a preparation based on microorganisms of the species BacillusSubtilis during the recommended 15 hours. To determine the activity limits of the enzyme preparation, the duration of the study is chosen in the range of 1 hour and 24 hours.

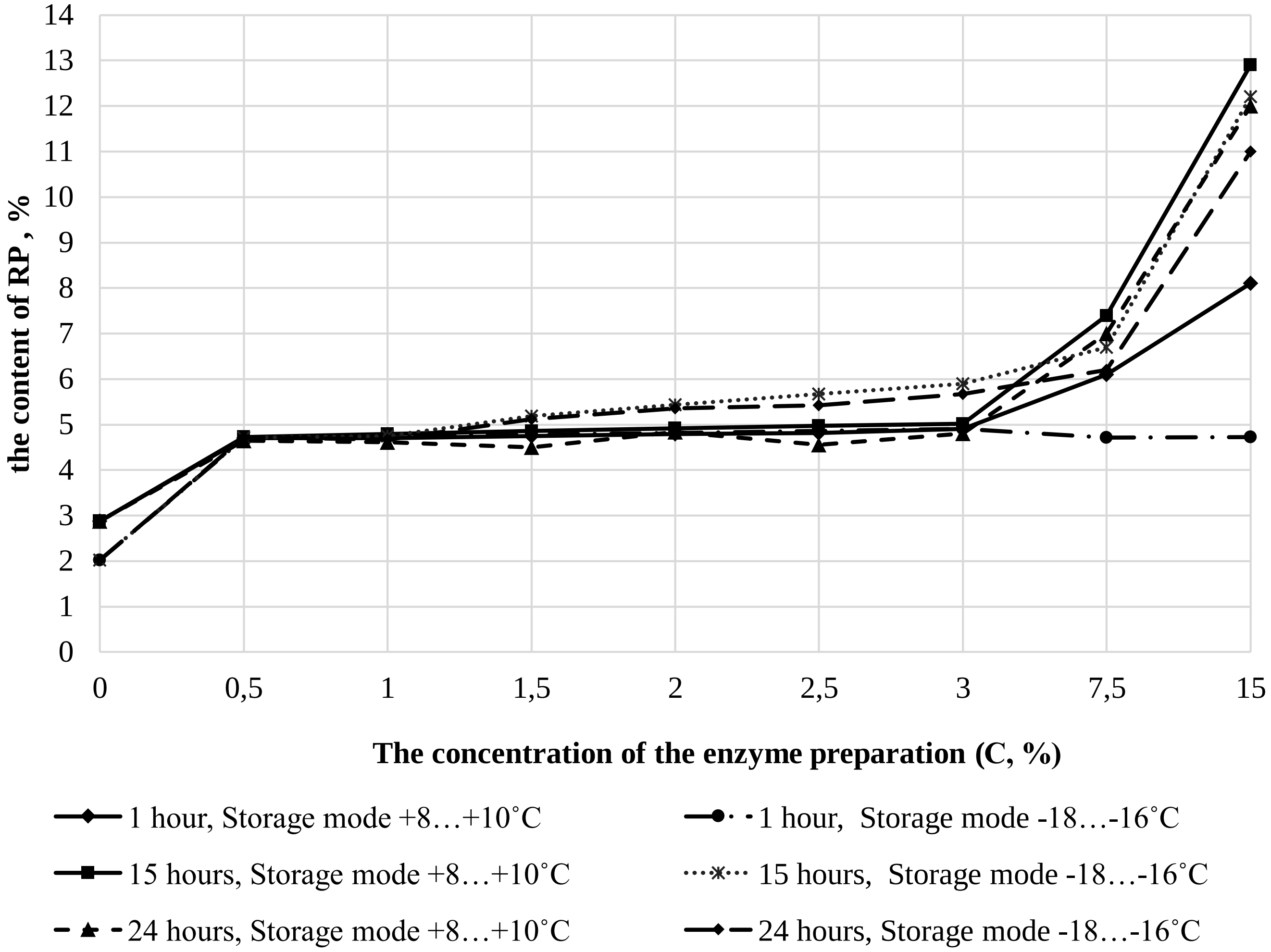


**Fig. 4 The kinetics of formation of RP (%) depending on τ (h)**

As can be seen from the diagram of increasing the duration of the enzymatic process, there is a decrease in the content of RP in the product under study. This is due to the rapid degeneration of microorganisms and the ability to use pectin, which reduces the yield of the ready product. In addition, 24 hours research is characterized by a high level of labor intensity and has a higher cost than conducting studies lasting 15 hours and 1 hour. Results obtained after contact of the product with the enzyme preparation for 1 hour indicate a short-term effect of inefficiency.

## Conclusion

Thus, the optimal parameters of the process are: 55°C, 15 hours, 7,5%. The trends confirmed that the increase in the duration of fermentolysis, even in the presence of unfavorable starting characteristics of the product, shows a significant increase in the content of RP (%) in the studied samples of pumpkin puree . The duration of fermentolysis should be within 15 hours, since during the 24-hour process the pectin content in the samples decreased. In addition, the resultant content of RP (%) in the source product is influenced by the storage mode and the quality of the pumpkin. Because low-temperature storage significantly slows down the formation of the RP (%) and negatively affects its resulting output. That is why, in this case, the enzymatic processing of pulp of the pumpkin is most appropriate, because after picking the seeds from the fruit of the pumpkin, its outer shell is damaged, which makes it impossible to store the fruit of the pumpkin at another. temperature modes differ from low temperature. At the same time, considering the effectiveness of the enzyme preparation on samples of pumpkin stored at +8...+10ºC and excellent organoleptic parameters, it is possible and appropriate to use the drug to the fruits immediately after harvesting. The conducted studies have shown the possibility of obtaining pectin substances from pumpkin pulp and the ability to predict its further use in the food industry.

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# Budgeting in Anti-Crisis Management

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***Abstract***

The economic essence of budgeting as a tool of anti-crisis management in accounting is considered. It is determined the role of management accounting information as the source of information in the budgeting system. The task and the classification of functions of budgeting in anti-crisis management are characterized. It is concluded that the use of management accounting information allows budgeting not only individual business processes but also the enterprise as a whole, and considering it as a single integral business process.

**Keywords:** budgeting, anti-crisis management, accounting, management accounting, business processes, budgets

**JEL Classification:** G 33, D 57, M 21, M 40, M 49

**Introduction**. In conditions of market competition, uncertainty and risk, enterprises seek to achieve the highest financial results by reforming both the internal structure of the enterprise and management methods. The deterioration in the financial position of an enterprise can occur both internally and externally. However, such a reason may be a variant of inefficient enterprise management, which could lead to bankruptcy of the enterprise.

**Research analysis and problem statement.** The study of scientific literature made it possible to conclude that a holistic scientific and methodological approach to the system of managing the activity of an industrial enterprise in conditions of uncertainty and risk that can be applied at all enterprises is absent, therefore, the introduction of a budgeting system for the implementation of anti-crisis management tasks is an actual topic of research. The purpose of the article is to determine the place of management accounting information and budgeting in anti-crisis management.

Budgeting (planning, budgeting) is a system of coordinated management of separate structural units of an enterprise that uses certain financial instruments - budgets, on the basis of systematic processing of economic information and balanced financial indicators for the achievement of strategic tasks in a dynamically changing environment. As it was proved earlier, it is possible to achieve a high level of activity and to avoid a crisis by introducing an effective anti-crisis management, which is intended to predict the emergence of a crisis, take measures to reduce its risk, increase the competitiveness of business and prevent bankruptcy of the enterprise.

The most important component of anti-crisis management is a planning process, during which the development of plans (strategies) of the enterprise in the conditions of resource constraints is carried out. One of the most effective tools for modern planning is budgeting, which provides management of the company with timely, accurate and complete information. The main task of budgeting in anti-crisis management is to create a holistic management system to ensure the effective operation of the business entity through the targeted orientation and coordination of all actions involving the change of own and involved economic assets of the enterprise and the sources of their formation, in order to identify the symptoms of the crisis on early stages and reduce its impact on financial performance.

An effective budgeting system is aimed at developing and implementing measures that allow: to adjust the activities of all structural subdivisions of the enterprise to achieve the planned financial result, allocating areas of responsibility by appointing responsible persons and distributing the functions of management between the heads of divisions; to accelerate the information exchange and interaction of structural subdivisions of the enterprise with each other by introducing automated accounting and reporting technologies for the adoption of constructive managerial decisions;

to predict critical periods in the enterprise's activity, to determine the necessity and the maximum limit of external financing and optimize the financial flows of the enterprise, taking into account external and internal factors of influence by applying the most effective forms of organization for achieving their balance and simultaneous growth; to identify strengths and weaknesses in enterprise management and factors contributing to the emergence of a crisis, to make necessary management decisions to prevent bankruptcy; identify the risks of the company in a timely manner and develop models for efficient use of resources by choosing alternative solutions; to identify possible internal and external reserves of the enterprise in order to prevent the crisis phenomena or minimize its negative consequences; evaluate the effectiveness and impact of the internal control system on the accomplished goals and objectives.

The generalization of scientific ideas to the definition of the concept of budgeting functions of both foreign and domestic scientists made it possible to distinguish the main ones: planning, organization, stimulation, control. In our opinion, budgeting in the information provision of anti-crisis management has certain features, so this classification should be supplemented. The refined classification has the following form:

1. Planning: the definition of the goals and tasks of the enterprise, the development of

action plans and the adoption of alternative solutions aimed at identifying the internal and external factors of influence that may lead to a crisis; communication - bringing plans to heads of structural divisions and centers of responsibility.

2. Organization: target orientation and coordination of various activities; creation of a holistic management system for all types of activities aimed at preventing the crisis of the enterprise.

3. Stimulation: motivation of employees to achieve the goals of the enterprise; courses for managers .

4. Control: control over the implementation of the budgets and results of the enterprise activity and its structural divisions; assessment of the influence of the decisions taken on the activity of the enterprise.

All activities of structural units are reflected in budgets, which are consolidated at the level of business processes, services and enterprises as a whole. Schematically this is shown in Figure 1.

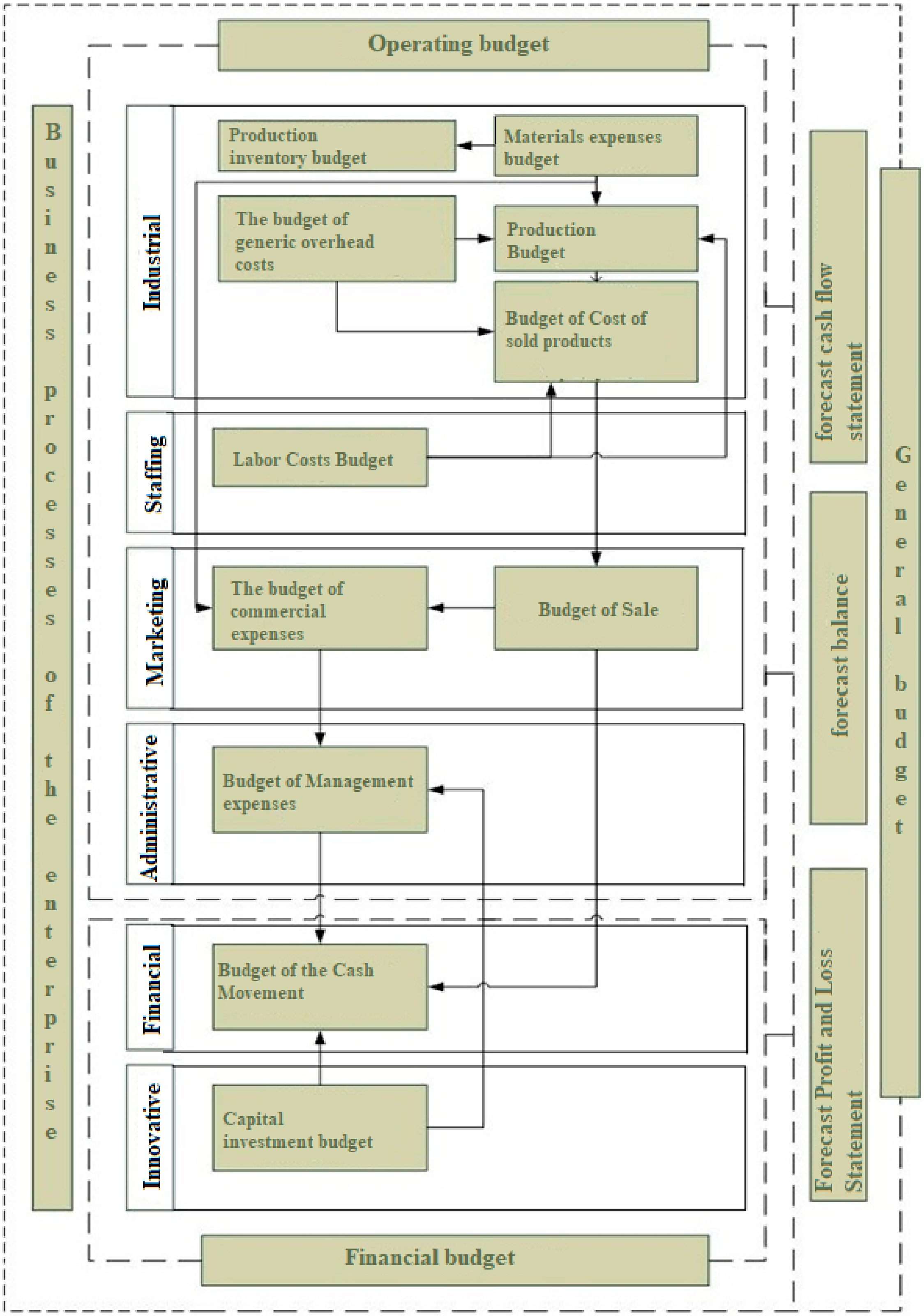


**Figure 1. Consolidation of budgets with business processes of the enterprise in the general budget of the enterprise** (Source: developed by author)

The budget thus becomes a highly effective anti-crisis management tool that allows both in real-time and by individual results to monitor the activity and performance of each center separately, each business process and the entire enterprise as a whole through a system of plan-actual deviations.

**Conclusions.** It can be concluded that in order to achieve goals, anti-crisis management should use an integrated system of managerial accounting and budgeting. Using management accounting information allows to budget not only individual business processes but also the enterprise as a whole, and to consider it as a single integral business process. The direction of further research is the development of the organization of accounting and management in each business process of the enterprise in anti-crisis management.

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# Architectural Environment and Emotions

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***Abstract***

The article deals with the problem of assessing the emotional potential of the architectural environment with its visual perception. To determine the emotional state of the perceiving subject, it is proposed to use the principle of correspondence of visual information and emotional reaction to it. It is proposed to use a distinctive informational model developed by the author to assess the informative nature of the architectural environment. Unlike probable and statistical model, it is based on the sensitivity of the human visual system to the perception of differences in the elements of the dimensional structure of the architectural environment. The formula for determining the amount of visually perceived information is given. The unit of information measurement is an eler (elementary differences). The method proposed for assessing the harmony of the dimensional structure - the basis for the comfort of visual perception and, as a consequence, the emotional potential of the architectural environment. Such a technique will simplify the psycho-physiological studies of visual perception of the human habitat and its design with predetermined (desired) emotional properties.

**Keywords:** emotion, visual information, architectural environment, distinctive information model.

What is the significance of human emotions in social development? In the process of communication, people form consciousness and conscience as the highest good record before themselves and society. The presence of consciousness enables a person to plan, think through his actions, conduct an internal dialogue with himself and consider various ways of his behaviour in his imagination. Being formed in the process of communication between people, consciousness is a necessary condition for their involvement in groups. The society forms from the participation of separate people into groups. Moreover, it is, above all, a system of connections between them. The highest achievements of human culture and science, art and technological progress are also connected with social experience as the most complex manifestations of a person's mental activity. Emotions play an important role in culture.

In his monograph "The Creating Brain" [1] P.V. Simonov divides emotions into positive and negative. One’s negative emotions (envy, hatred) engender wars, social cataclysms; positive ones generate inspiration, creativity, cooperation, constructive activities that determine the development of society. Positive emotions give a person psychological comfort. Therefore, he seeks to receive them again and again. To get positive emotions, a person listens to music, goes to the picture gallery, walks to the forest, to the mountains, where, unexpectedly, he gets beautiful landscapes, breathtaking air prospects, fantastic piles of rocks, fabulous chiaroscuro. Positive emotions for a person are a psychological drug. For positive emotions, he pays much money: for a symphony orchestra concert, for a trip to the Alps or the Maldives, for a trip to the Himalayas or the Amazonian forests. Moreover, everything is done for obtaining spiritual comfort, positive emotions, which are the result of the perception of sensory information from the surrounding world.

Information is known to be divided into pragmatic, semantic and syntactical (structural). The information theory of emotions, which was developed by P.V. Simonov [2], is based on the practical component of the information flow from the external environment. Another concept – activation, – by Lindsay-Hebb, relies on semantics. We will try to define the relationship between the structural (syntactic) information and the emotions it generates.

In reinforcement of our intentions, we cite a monograph from the staff of the Scientific Research Institute of Neurophysiology [3]: "The informational approach obviously has good prospects for studying the relationship between brain processes and the psyche. Indeed, if the information, which is in the aggregate of nervous processes and in the mental image, is equivalent, then it is the analysis of the informational content of physiological processes that will contribute to the study of the connection between cerebral and psychic phenomena" [3, p.10]. Such research was conducted for decades under the supervision of Academician P.V. Simonov. We do not doubt that such studies are significant for establishing this pattern. However, emotions cannot be described in words and expressed in quantitative form. How can we assess the "mental image" and what is meant by this phrase?

Apparently, we mean a psychological reaction to external stimuli in the form of emotional states – "surprise", "oppression", "fear", and others, but how to evaluate information coming from the external environment? If using the probability-statistical model, how to determine the probability of satisfying "needs"? Moreover, how to determine what needs are available to the perceiving subject at the time of perception?

As we see, the realisation of the idea of "studying the connection between brain and psychic phenomena" faces many uncertainties. The author of this article proposes to evaluate informational processes not in the brain structures, but on the "input" - the incoming structural information. At the "exit" you can record an emotional response to the stimuli of the external environment. Thus, the perceiving subject is regarded as a "black box". Emotional reactions of the perceiving subject psychologists can evaluate by frequency characteristics of cardiac contractions. When evaluating emotional responses, it is proposed to use the correspondence principle: each emotional response corresponds to the informational feature of the external environment. We accept this provision as a postulate because for healthy people the lack of correspondence is impossible. If there is no correspondence, the perceiving subject will lose its orientation in space. First of all, there is a visual perception of the architectural space.

The architectural medium consists of elements of different geometric modalities. They can be linear, rectangular, angular, curvilinear, volumetric-plastic and the most incredible irregular shape, as in a pile of construction debris. Moreover, the relationship of the dimensional structure of all geometric modules contains structural information, which corresponds to a sensory response to the perception of this data. Each link is the source of elementary information, which gives rise to a sensory response-sensation. The sum of omissions forms the emotion generated by the sum of elementary information.

Structural information, concluded concerning two elements of the dimensional structure, is determined using a distinctive information model [4, p. 225-231].

$$u = k \lg \frac{r_i}{r_j}, \tag{1}$$

where:

$u$ – visual information regarding two elements of a dimensional architectural form;

$r_i$ and $r_j$ – are elements of the dimensional structure of the architectural medium, expressed in centimeters, meters (for linear and rectangular modality), degrees (for angular modality); when determining the informativeness of the elements of the curvilinear modality environment, the parts of the dimensional structure take the angles between the tangents to the curve of the curve at points that divide it into equal segments;

$k$ – a factor that takes into account the differential sensitivity of the human visual system; with sensitivity, $C = \frac{1}{33}$ $k = 76{,}56$, [4].

$$U = \sum_{i}^{n} k \lg \frac{r_i}{r_j}. \tag{2}$$

Structural information, determined by the above formula, is measured in elementary differences (eler – the English transcription of Russian “элер” – “элементарное различие”), with a larger dimension being placed in the numerator, a smaller fraction in the denominator, in which case the information will have a positive value.

Structural information, enclosed in tonal relations of the architectural environment, can be determined by the different thresholds of visual distinction of the tonality, taking into account the tolerance of the relationship, i.e. those relationships that allow us to disregard subliminal differences. The same conditions for determining structural information will also apply to colour relationships.

It is necessary to make structural-level differentiation of its elements of the dimensional structure, to unify the computation of structural information, taking into account the variety of physical parameters of both individual parts and architectural space as a whole. We adopted the following classification of elements of the architectural space:

– urban level (level of the whole), including such elements of architectural space as the gaps between buildings, the width and depth of streets, areas, the overall size of buildings;

– the level of the parts of the whole, including such elements of the architectural environment as the cour d'honneur and avant-corps, porticos, large sections of buildings along the vertical;

– the level of elements of architectural form, including window openings, piers, intercolumniation, vertical inter-window spaces, cells of glass stained-glass windows;

– the level of details of the architectural form and space: above window hood molds, window frames, details of entablatures;

– microstructural level (tactile): elements of the texture of surfaces, grass lawns, leaves of crowns of bushes and trees.

The rules for calculating structural information are established by the researchers before the beginning of the experiment to identify an emotional response to the perception of the architectural environment. It is necessary to take into account such qualities of information as its novelty. The fact is that a particular part of the information is in the memory of the subjects and the emotional reaction to it will differ from the perceived for the first time. In advance, assuming that the new information will evoke a stronger emotional response than the familiar, stored in the memory of the subjects.

It is necessary to dwell on one aspect of the perception of architectural space. It will be about the dynamism of the informational flow, which entails the dynamism of changing emotional responses. When the architectural space is perceived during the movement, the structural information of the architectural environment acquires the "flow" qualities of the informational flow: the angles of perception of the facades change, and the perspective angles of the horizontal lines change. Notwithstanding the law of constancy of perception, the dynamics of the informational flow is present. Some elements of the architectural environment in the process of "dynamic" perception disappear from the field of vision, some "swim" because of closer ones. However, the most critical moments of dynamic perception are the borderline moments of the transition from one space to another, from a close space to an open, wide. Here one can expect a surge of emotions, surprise, admiration and other positive emotions.

Moreover, conversely, when moving from an ample space to a close, there may be an emotion of discomfort, depression, even fear. Similar emotions are experienced by the passengers of the train when they enter the tunnel. When the train leaves the tunnel, a beautiful picture of the mountainous landscape opens suddenly with a breathtaking aerial perspective. There is an emotion of freedom, relaxation, joy. Of course, it is tough to assess the information content of a mountain landscape. However, to determine the dynamics of the informational flow, and, consequently, the dynamics of changing emotional states in the process of moving in the architectural environment is an entirely solvable task.

The examples above illustrate the "pulsating" environment that defines the "pulsation" of the emotional states of the people who perceive it. However, such qualities of the architectural environment are not always acceptable, when the physical parameters of space dramatically change because it can generate stressful emotional states, feelings of discomfort.

The comfort of perception is one of the manifestations of positive emotion. It is associated with minimal actions when perceiving a significant amount of structural information. P.V. Simonov in his monograph [1] noted that "Throughout their existence, people have repeatedly been convinced of the advantages of certain forms of organisation and their actions, and the things they create. The list of these forms includes the proportionality of the parts of the whole, the absence of unnecessary parts that do not work on the basic design, the coordination of the combined efforts, the rhythm of repetitive actions, and much, much more. And, further: "Aesthetic pleasure is a positive emotion associated with the satisfaction of a minimum of three needs: cognition, the economy of the force of weapons with knowledge, skills and abilities that lead to the achievement of the goal in the shortest and the right way" [1, p. 47].

The author dared, single out in the quote of the famous scientist the most vividly reflecting the means of achieving and the result of the manifestation of positive emotions: the proportionality of the parts of the whole and the saving of forces. It is the economy of forces, as a manifestation of the principle of the least action, that is achieved using the proportionality of the parts of the whole [4]. The proportionality of the architectural environment is achieved by the informational unity of the relations of all, or the majority, elements of its dimensional structure. Any proportionality based on the belonging of its elements to a proportional series of quantities, which is a geometric progression:

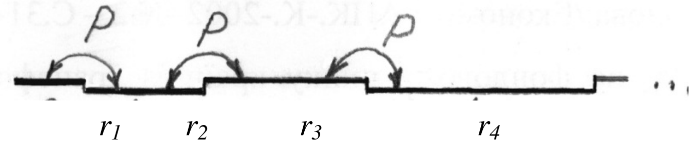


*Fig. 1. Proportional series of quantities.*

As can be seen from the figure $\frac{r_1}{r_2} = \frac{r_2}{r_3} = \frac{r_3}{r_4} = ....$

The mathematical dependence between any members of this series of elements looks like this:

$$\frac{r_i}{r_j} = p^s , \tag{3}$$

where:

$r_i$ and $r_j$ – are any members of a proportional series of quantities;

*p* – the basis of a proportional series of quantities is the ratio of the two neighbouring terms of the series;

*s* – is the integer of the natural number corresponding to the difference of the ordinal numbers of the terms of the proportional series, $s = j - i$.

If we substitute (3) in (1), we obtain:

$$u = k \lg p = sk \lg p . \tag{4}$$

In the last expression, *k* and *p* are *const* for any proportional series. Therefore – *const* for any proportional series of quantities and is its information module $\mu$. If during the calculation of structural information, it turns out that the information is multiple $\mu$, for example, ten eler, this is evidence of the membership of the dimensional structure elements entering into the relations, to a single system of proportionality.

Information has the properties of discreteness and disabilities. Suppose that the visual information *U* is divided into equal portions, and this took *N* "division" operations. If one part increases by ten times, the number of actions for the division will be reduced by a factor of 10. Thus, the visual system will spend ten times less effort (action) on the perception of visual information *U*. The fewer operations the optical system makes, the more comfortable the understanding of visual information will be. This is the principle of least effort.

The visual information enclosed concerning two neighbouring elements of the dimensional structure is called the information step of the relation (*U*). The magnitude of the information module relative to the information steps that it links characterises the information unity of this set of information steps. If we accept the maximum unity index for 1, it can be achieved only if the informational steps are equal, i.e. their informational module will be equivalent to the information steps, i.e., $u_i = u_j = \mu_{ij}$. The formula determines the index of proportionality $\Pi_c$:

$$\Pi_c = \frac{2\mu_{ij}}{u_i + u_j} = 1.0\,. \tag{5}$$

In the same way, one can determine the index of proportionality of any pairwise taken neighbouring information steps of the architectural form or the environment as a whole.

The comfort of perception as a manifestation of positive emotions is the most characteristic in the field of art. "It is important not only to forget that feelings, emotions, experiences are not the goal of art, but the consequence of the perception by the listener, the reader, the viewer of the" message "about the world that the images of the artistic work bear to him as a result of the artist's knowledge of the" humanized "reality. True musicians do not express feelings in music, but make music into feelings - this amazing remark is true not only for musical creativity "[1, p. 28].

We will try to extrapolate this idea of P.V. Simonov into architecture, especially since "architecture is music that has frozen in stone" (Gogol).

The harmony of the architectural form and the architectural environment as a whole can be quantified if we consider it as a sensually perceived phenomenon from the general scientific sense of perception. It consists of the fact that any living system to ensure its vital activity tends to consume the maximum amount of information coming from the external environment, with the minimum costs already accrued for the assimilation of the incoming. It is quite logical, for development is the accumulation of information, and if the system spends more than it receives, it will not develop. Consequently, this growing sense of information processes in living nature reflects the principle of least action.

The principle of least action is considered to be the ultimate meaning of all physical laws in various sciences. Sensual perception obeys the laws of physics, as it is the result of physicochemical processes occurring in our nervous system under the influence of external stimuli. Therefore, knowing that the human body evaluates the information coming into it from the positions of least action, let us consider the problem of assessing the proportionality of the architectural form through the prism of this principle.

If we consider visually perceived information as a result of the interaction of data coming through the visual system with the information memory of a person, then we will judge the rationality of this communication by how many microprograms of our mind were used in the process of perception and how much information was accounted for by one microprogram.

As early as 1912, M.V. Bancroft gave the following interpretation of the principle of least action for biological systems: "The changes affecting the system (biological) are such that they tend to minimise the perturbation of the external order" [5, p. 12]. In other words, the information processes in the biological system proceed in such a way as to maximise the information of the outside world to perform a minimal amount of actions for its assimilation.

Since the information, according to our interpretation of A. Kolmogorov, is the "length of the perception algorithm", and the information modules are separate operations linking the neighbouring information steps, the efficiency of perception will be determined by the amount of information per one such operation. This value will reflect the magnitude of the action of the visual system and the information ordering of the architectural form, that is, its proportionality.

The number of information modules contained in two adjacent information steps is the modular capacity (E) of the sum of these information steps:

$$E = \frac{u_i + u_j}{\mu_{ij}}. \quad (6)$$

The modular capacity of a composition containing m pairs of information steps will be:

$$E_к = \sum_{2}^{m} \frac{u_i + u_j}{\mu_{ij}}. \quad (7)$$

The measure of the harmony of a composition containing m pairs of information steps will be:

$$M_г = \frac{\sum_{2}^{m}(u_i + u_j)}{E_k}. \quad (8)$$

The measure of harmony characterises the strength of the information unity of the relations of the dimensional structure of the architectural composition. The stronger the information link between neighbouring information steps, the less the number of information modules will fit into their summary information. The more information will come from one information module, the higher the measure of harmony, the more comfortable the perception of the architectural form.

If we accept A. Kolmogorov's (1965) position that information is an expression of complexity, then in the last formula in the numerator we get complexity. Information unity of the architectural form is a consequence of its proportionality. Therefore, the total modular capacity in the denominator will characterise the degree of disorder in the architectural form.

Thus, the measure of harmony is a function of the complexity and orderliness of the architectural form and can be viewed as an informational interpretation of the aesthetic measure of Eysenck [6, p. 250-260].

Two squares with the same type of division are listed below to illustrate this message, but with different ratios of the elements of the dimensional structure (Fig. 2). Below them are information fields that allow the reader to calculate the measure of the harmonicity of each square independently. In the centre of each cell the information step of the ratio of its sides is indicated, and near the arrows - the information step of the rate of the elements is pointed to by the arrows. We give the final result of the calculations.

The measure of the harmony of the square A is 6.16 eler; the square B is 8.2 eler. Most participants in the expert survey, who were asked about the comfort of visual perception of the squares, favoured the square of B.

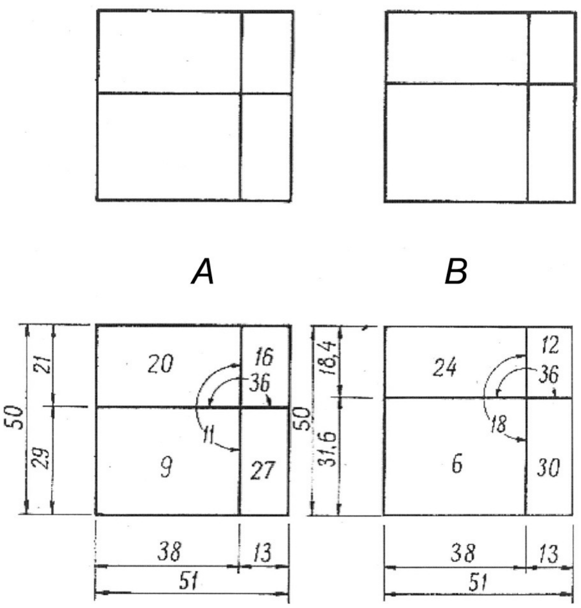


*Fig. 2. Information fields of squares A and B*

The comfort of perception is a positive emotion that is born with the understanding of visual information, which is created by the architectural environment. It is the most potent and inexhaustible source of emotion. It can not be eliminated from our lives. It cannot be discarded as a failed painting or turn off the TV if the unpleasant music is playing. The architectural environment surrounds us, generating both positive and negative emotions. In it we live, our future depends on what will be tomorrow.

An outstanding British politician of the 20th century, Winston Churchill once said: 'We shape our buildings; thereafter they shape us'. Harmonious architecture, generating positive emotions, forms a congenial personality, and harmonious individuals establish a peaceful society. Therefore, the problem raised here is of civilizational significance. Solving the task of formalising emotions depending on the informative nature of the architectural environment will allow us to design our environment in the future with pre-defined emotional characteristics.

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# Semantic Extensions of *Green/ Зелений* Colour Terms in Contemporary English and Ukrainian Fiction

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***Abstract***

The analysis of semantic properties of green/зелений colour in the English and Ukrainian languages conducted on the basis of dictionary entries and linguistic corpora data shows how colour categorization is shaped in language and fiction by both nation's common cognitive universals and their socio-cultural evolutionary processes. Corpora data analysis shows semantic extensions of green colour terms in fiction, which are explained in terms of individual authors' cognitive shifts within universal physiological parameters. Expressing personal emotions and implied pragmatic aims writers either create new colours or makes semantic shifts in the existing ones. Metaphors, metonymies, and similes serve basis to create extended *green/зелений* colour meanings. Synaesthetic shifts of colour perception also enrich colour semantics. Structural extensions of green colour are the combinations of colour term with quality or quantity modifier, which not only denote physical properties of colour, but also show colour emotional and psychological value for the speaker or writer.
**Keywords:** colour terms, semantic structure, corpus research, semantic extensions.

Semantic extension of colour terms is the linguistic process of widening words range of meanings by means of semantic shifts and semantic transference, which lead to polysemy [3, p.112]. In fiction semantic changes are carried forward by specific individuals (writers) who think in particular ways, although they can be constrained by physiology and guided by social values. The measurement of colour categories in literary texts provides a close look at the various propelling incentives in the domain that is probably universal [4, p. 34].

The semantic extensions of green colour term in English and Ukrainian fiction are not yet studied in details which determine the **aim** of our research. The key **method** used in the study is newly refined descriptive methods, bases on the data from corpus [5]. Corpus-based research of *green/зелений* usage in both languages provides objectivity, reliability and accuracy of the received data, presenting not simply quantitative findings, but also exploring the importance of these findings for semantic structure of green colour.

Measurable change of colour meaning progresses through diverse trajectories in closely related languages whose social milieus are radically distinct. Thus, variations in colour terms in the English and Ukrainian languages can be explained in terms of individual cognitive shifts within universal physiological parameters. Still sometimes a socially enforced conservatism creates tension between the preservation of traditional colour categories and the addition of new ones, which results in the creation of deep semantic structure of colour terms in language. While the model of individual author cognition explains how colour categories change at the basic level, a social model accounts for differences between communities. Cognitive and structural shifts of colours meanings introduced by writers in fiction gradually become common and generally accepted in society, extending the semantic structure of colour terms.

Existing research in colour naming and categorization primarily reflects two opposing views: according to a *Cultural Relativist view* (F.Boaz, E.Sapir, B.L.Whorf, L.Wittgenstein) colour perception is greatly shaped by culturally specific language associations and perceptual learning, and a *Universalist view* (E.Rosch, A.Wierzbicka) [6, p. 23–45] emphasizes pan-human shared colour processing as the basis for colour naming similarities within and across cultures. Our research presents an alternate view that specifies how colour categorization is shaped by both common cognitive universals and socio-cultural evolutionary processes. The research of dictionaries entries and corpus-based analysis reveal differences, as well as similarities between English and Ukrainian *green/зелений* colour semantics and its extensions in fiction.

Semantic changes of colour terms always result in colour semantic shifts, due to bilateral character of linguistic sign. Combining expression side and content side, colour meaning changes with every change of its form and thus extends semantic structure of the word.

Whereas any colour term can be used for description and identification in literary texts, it appears that only the most basic terms are regularly employed for structural type modification [1, p. 176]. Thus in fiction basic colour terms are often accompanied by additional attributes or value characteristics of different quality.

Extended colour terms modification is common in ordinary language use. Structural extensions of colour terms can be understood as sets or semantic and lexical fields of one particular colour. According to the semantic properties of colour modifiers, structurally extended colour terms in English and Ukrainian fiction can be grouped into such classes: colours with light-darkness, intensity and emotional value, temperature, texture and material display and basic colours and hues combination.

Any given colour can be described in terms of its *quantity* or *value*. Value is defined as the relative lightness or darkness of a colour. It is an important psychological characteristic of colour as light hues are often associated with positive emotions, while black with negative ones. Such colour perception peculiarities are based on the archaic stereotypes of world perception, and originate from the day-night opposition, in which day is associated with light, familiar, well-known things, and night is treated as dark, unknown, strange and dangerous. For example, Eng. *dark horse* is 'a competitor in a race or contest about whom little is known', and Ukr. *світлиця* is 'well-lighted room in the house, which is used only during holidays and religious celebrations'.

Ordinary language can be used for developing a system of colour modifying structures. The elements of these are adjectives and colour terms, the adverb/intensifiers Eng. *very, extremely, almost, completely;* Ukr. *дуже, абсолютно, надзвичайно* and adjectives which refer to colour or shade of colour. In literary texts colours with intensity display are used to describe setting and characters. At the same time high intensities of green colour attract and give feelings of activity, as for instance, in Eng. *dark olive, dark spring green, dark turquoise* and Ukr. *яскраво зелений, темно-весняно-зелений*. Low intensities are quiet and subdued and are seldom noticed (Eng. *pastel green, medium sea green*; Ukr. *пастельно-зелений*). Compare the following examples:

(1) *Charles dropped into a deep sleep where lumbering Thurber cartoon figures with guns in their hands chased him through a landscape of pastel green, dotted with red flowers* (S. Brett *Cast in order of disappearance*);

(2) *Ice-brightness and the rare intense green flare of ocean sunsets; lightning's tongues fields furred under a harvest moon all the honey-strokes of colour* (C.Evans *Cometary phases*).

The modified colour terms of emotional value are also formed by combinations of adjectives and colour terms [6, p. 103]. Still unlike colour terms with intensity display, this group is unique for every writer, as he expresses his own vision of world and gives his personal evaluative characteristic of colour. For example, *green / зелений* can be Eng. *strong, luxury, precious*; Ukr. *щедрий, багатий, приємний оку*:

*Завдяки* <u>*щедрій зелені*</u>, *вишнякам та соняшникам, а слізьми загорьована осінь, безніжна зіма або холодна несмілива провесінь начеви валяють, дужче підкреслюють усі злидні, убозтво, безпросвітність життя* (О.Іваненко *Марія*).

Some adjectives, which are added to colour terms to intensity colour, are already common in everyday language and are not perceived by readers and writers as figurative [2, p.41]. For example, *deep green* in the following citation sounds common comparing to other metaphors in the verse:

*Apples Where are the old apples, the conical, uneven apples, obscurely ribbed, ripening to deeper yellow, the crimson-cheeked apples, marbled and washed with clear red, the* <u>*deep green apples*</u> (F. Pitt-Kethley *Sky ray lolly*).

Temperature affects peoples' eyes interpretation of the colour tints in art, but in fiction it creates additional evaluative connotations. Warm hues suggest aggression, sunlight, heat, stimulation, cheerfulness, heaviness, and dryness. Cool hues imply sky, water, distance, shadows, quiet, lightness and wetness. Green hues can be both warm (Eng. *golden green, sunny green*; Ukr. *хакі, жовто-зелений* ) and they will create positive light atmosphere, or they may be cool (Eng. *neon green, iceberg lettuce*; Ukr. *колір замороженої м'яти, аквамариновий*), which depress, irritate readers or even make them be afraid:

*Ну й літо ж видалось! Таке на Волині рідко буває. Сонця того, зелені тенплої, співів* (М. Олійник *Леся*).

Texture or material of which coloured things are done let readers easier imagine specific features of colour in this or that situation. This quality is natural still it often implies evaluative connotations. The term *texture of the colour* means, the change in the colour because of the application of texture of the surface. However implication of texture of colour is more meaningful than the usage of colour alone. Colour connotative meanings are added to those of the texture or material. For instance, such modifiers as Ukr. *оксамитовий, шовковий, атласний* denote beauty and tenderness of green grass.

Combinations of different colours and hues make separate category of structurally modified colour terms. As far as colour combinations are used in fiction for nature description, green is often modified by other basic colours, especially by yellow, blue and red. *Yellow-green / жовто-зелений*, scientifically called *chartreuse*, is typical colour of grass and the sky in the evening. This combination occurs very often in natural conditions, because green and yellow are neighbouring colours of spectrum. Such structural colour modification can also be explained by the natural process of fruits and crop plants ripening, when for example, green apples gradually become yellow. In this case colour of apple makes one colour category, no matter whether it is green or ripe. Contemporary writers base their green-yellow colour characteristics on personal perception of physical air conditions. For example, in Ukrainian and English prose texts forest or step can be of green-yellow colour.

Structural extensions of green colour add new connotative meanings to it semantic structure. Not only physical features of colour, such as light-darkness, intensity, temperature, texture are characterized, but their emotional value as well. Combinations of colours and hues result in new symbolic and associative meanings, which are based on writers' and speakers' perceptual experience and cultural knowledge. Further research can be held to systemically analyze evolution in colour meanings in a cross-linguistic and cross-cultural perspective.

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# Basic Notions and General Characteristics of Conflict Communication

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***Abstract***

Conflict communication is a complex process in which humans initiate and maintain their social relationships and emotional contacts with each other by means of verbal and nonverbal signs. People communicate differently that often causes misunderstandings. Conflict communication is defined as a natural disagreement resulting from individuals that differ in their attitudes, beliefs, values or needs, and is presented in their speech. Conflict tends to be accompanied by significant levels of misunderstanding that considerably exaggerates the perceived disagreement between interlocutors. Conflict communication has several general characteristics. It arises because of people's miscommunication and develops in accordance with the speakers' goals and objectives. Thus, conflict can be of different intensity levels: low, medium, and high, which presuppose various styles in facing conflict: avoidance, blaming and power usage.

**Keywords:** conflict communication, interpersonal conflict, pseudo-conflict, content conflict, value conflict, ego conflict.

***This paper aims*** at studying the basic notions of conflict communication and outlining the main scientific approaches in conflict communication analysis.

Communication is a social interaction where at least two interacting agents share a common set of signs and a common set of semiotic rules. There is the sender, who encodes messages and the receiver, who decodes messages. It is important to understand that during communication the role of sender does not belong exclusively to one person and the role of receiver to another. Instead, the processes of sending and receiving are constantly being reversed [4, p. 7]. However, the interlocutors are affected with the context and their communication skills, attitudes, and the experiences. In many cases, the message sent differs from the message received because of noise, which leads to miscommunication and results in conflict.

In psychology, conflict is a struggle resulting from incompatible or opposing needs, drives, wishes, or demands [7]. In other words, a clash of interests, values, actions or directions often sparks a conflict. Conflicts refer to the existence of that clash. Psychologically, a conflict exists when the reduction of one motivating stimulus involves an increase in another, so that a new adjustment is demanded.

Interpersonal conflict represents a struggle between two or more people as a state of discord caused by the actual or perceived opposition of needs, values and interests. Conflict as a concept can help explain many aspects of social life such as social disagreement, conflicts of interests, and fights between individuals, groups, or organizations. Without proper social arrangement or resolution, conflicts in social settings can result in stress or tensions among people [5, p. 467-503].

There is the distinction between the presence and absence of conflict with the difference between competition and co-operation. In competitive situations, the two or more individuals have mutually inconsistent goals. Therefore, competitive situations, by their nature, cause conflict. However, conflict can also occur in cooperative situations, in which two or more individuals have consistent goals, because the manner in which one person tries to reach their goal can still undermine the other individual.

Therefore, conflict communication is the dynamic process, the model of social interaction, which includes at least two counterparts, who compete with each other on the ground of opposing needs and demands.

Conflict is apt to occur wherever human differences meet. It is the clash of opposing beliefs, opinions, values, needs, assumptions, and goals. Conflict can result from honest differences, from misunderstandings, from anger, or from expecting either too much or too little from people and/or situations. Conflicts can be handled rationally or irrationally. In addition, conflict does not always require two or more to argue [6]. A person can sometimes be in conflict with oneself. This occurs when an individual finds oneself having to choose between two or more mutually exclusive options.

Interpersonal conflict occurs when the same type of opposition process occurs between two or more individuals. Such encounters can be prompted with differences in perceptions and interests, a scarcity of resources such as money, time, or position, or by rivalries in which we find ourselves competing with someone else. Those involved in either an intrapersonal or an interpersonal conflict usually feel pulled in different directions at the same time [4, p. 181-185].

People adopt a number of ***different styles in facing conflict***.

First, it is very common to see a person who *avoids or denies* the existence of conflict. In this case, the conflict often lingers in the background during interaction between the participants and creates the potential for further tension and even more conflict.

A second response style is that of one person getting mad and *blaming the other* person. This occurs when a person mistakenly equates conflict with anger. This stance does nothing to resolve the conflict and in fact only serves to increase the degree of friction between the two participants by amplifying defensiveness.

A third way, which some people use to resolve conflict is by *using power and influence* to win at the other's expense. Other people appear to compromise in resolving the conflict, but they subtly manipulate the person in the process, and this, again, perpetuates the conflict between the two parties and compromises the trust between them [1].

In the presses of communication, ***conflict can be categorized*** in different ways.

First, it is possible to identify the *type of goal or objective* about which a conflict revolves. Goals or objectives can be non-shareable (For example, two teams cannot win the same basketball game), or they can be shareable (One team wins some games and the other team wins some), or they can be fully claimed and possessed by each party to the conflict.

Second, conflicts can be categorized according to their *level of intensity*. In *low-intensity conflicts*, the interactants do not want to destroy each other; they devise an acceptable procedure to help control their communications and permit them to discover a solution that is beneficial to each. In *medium-intensity conflicts*, each party feels committed to win, and winning is seen as sufficient. No one feels that the opposition has to be destroyed. In *high-intensity conflicts*, however, one interlocutor intends to destroy or seriously hurt the other. It is in these conflicts that victory must be total [2].

A conflict can also be classified as ***a pseudo-conflict***, ***a content conflict, a value conflict,*** or ***an ego conflict***. Although not really a conflict, a *pseudo-conflict* gives the appearance of a conflict. It occurs when a person mistakenly believes that two or more goals cannot be simultaneously achieved. Pseudo-conflicts frequently revolve around false either-or judgments (Either I win or you win) or simple misunderstandings (failing to realize that you really agree with the other person). A pseudo-conflict is resolved when the speakers realize that no conflict actually exists.

A *content conflict* occurs when individuals disagree over the accuracy of a fact, the implications of a fact, a definition, or the solution to a problem. If the opponents realize that facts can be verified, inferences tested, definitions checked, and solutions evaluated against criteria, then they can be shown that a content conflict can be settled rationally.

In contrast to a pseudo-conflict and a content conflict, a *value conflict* arises when people hold different views on some issue of a particular nature. The realistic outcome of such an encounter would be that the counterparts would disagree without becoming disagreeable – that is, they would discuss the issue and learn something from one another, ever though they might continue to disagree. In effect, they would agree that it is acceptable to disagree.

*Ego conflicts* have the greatest potential to destroy a group. They occur whenever the opposing sides believe that winning or losing is a reflection of their own self-worth, prestige, or competence. When this happens, the issue itself is no longer important because each person perceives himself or herself to be on the line. This in turn makes it almost impossible to deal with the situation rationally [4, p. 9].

In any situation, problems can develop if people fail to deal with conflict appropriately. There are certain definite benefits to be derived from handling conflict effectively. Alan Fillcy in the book Interpersonal Conflict Resolution identifies four major values arising from conflict.

First, many conflict situations can function to eliminate the probability of more serious disharmony in the future.

Second, conflict can increase our innovativeness by helping us acquire new ways of looking at things, new ways of thinking, and new behaviours.

Third, conflict can develop the sense of cohesiveness and togetherness by increasing closeness and trust.

Fourth, it can provide people with an invaluable opportunity to measure the strength or viability of their relationships [3, p. 259-267].

Overall, there are different types of disagreements and problems that can arise during intrapersonal and interpersonal encounters. Particular conflict behaviour affects each of counterparts differently. Some people perceive themselves to be involved in a conflict if they are deprived of a need or if someone impinges on their territory or disagrees with them about the way, they define a particular role, whereas others do not.

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# Transformation of Traditional Characters' Images in Contemporary English and Ukrainian Literary Fairy Tales

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***Abstract***

The contrast between Good and Evil is salient in fairy tales that aim at teaching children socially acceptable behavior. Conventionally, in contemporary both English and Ukrainian literary fairy tales the personages are strictly divided into the team of Good and the team of Bad. In accordance to *good/bad* criterion, all characters of literary fairy tales can be further subdivided into those who cause Evil; those who suffer from Evil; and those who create Good and fight against Evil. Similarly, functional classification of characters distinguishes those fairy tale personages who are perceived as *good* (the hero, the princess and the princess' father, the donor, the (magical) helper) and those who are believed to be *bad* (the villain, the false hero, the dispatcher). Good characters are opposed to bad in their appearance, social status and deeds. According to the unwritten fairy tale rule, *good* personages always win in the end. They are praised and rewarded because they are the protectors of moral virtues and social values, while *bad* ones are punished for their dishonest deeds.

**Keywords:** Good and Evil, *good* personages, *bad* personages, literary fairy tales.

Dualism seems to be deeply-rooted in human mind and is supported by the elaborate system of categorisation, acquired by people in childhood. Thus, binary oppositions *good/bad* in English and *хороше/погане* in Ukrainian tend to be the most vivid in children stories, namely fairy tales. This ***paper aims at*** studying the transformation of characters' images in contemporary fairy tales in the light of contrast between Good and Evil.

Literary fairy tale is a type of short narrative about fairies or other mythical or magical beings, especially one of traditional origin that involves a far-fetched sequence of events [5, p. 112–113]. Literary fairy tales typically feature such folkloric characters as fairies, goblins, elves, troll, giants or gnomes, and usually magic or enchantments.

Contemporary fairy tales are created by writers under the influence of Postmodernism. Thus, they are characterised by Postmodern play in the text, especially, on the level of personages with mythological creatures, as well as by the sense of moral freedom, which should not be confused with Postmodern defragmentation and desacramentality [6, p. 145]. Moreover, the role of recipient becomes very important. Unlike traditional fairy tales, literary ones, starting from the 80-s of XX century are written for children. Thus, some "unwritten prohibitions" exist for such stories [6, p. 214–225], in particular, 1) prohibition of pain (the hero does not usually feel pain in fight with his enemies); 2) prohibition of blood (blood of hero is not shown as well as blood of enemy, when the enemy is killed, he disappears, or turns into dust); 3) prohibition of death (positive characters cannot die, in case if they are killed they should arise from the dead at the end of the fairy tale); 4) prohibition of passion and combination of *good* and *bad* in one character (hero represents certain type of personal qualities: brevity, honesty, wisdom).

Contemporary Eastern European (Ukrainian) tales combine traditional folkloric structures with futuristic technological paraphernalia, while Western (English) tales more frequently combine innovative narrative strategies with established fairy tale tropes and characters. The goals of the former have tended more towards overt social criticism, coupled with the tale-teller's inherent desire to entertain, while the goals of the latter reverse the order of importance, but share the same basic purpose.

According to M.M. Bakhtin, literary fairy tales belong to separate genre of literature [2, p. 67]. However, as literary fairy tales originate from traditional tales, they preserve basic opposition *good/bad*, characteristic to folk tales. All events in literary fairy tales are organised on the basis of *good* and *bad* (*evil*) opposition. These stories serve to describe a particular moral, an action of goodness achieved through courage, sacrifice, and a helpful dose of magic. They centre on timeless issues of loyalty, honour, and brevity. Thus, their main rule is: good magic defeats evil magic, because only a person of all moral virtues can possess and use good magic [5, p. 112–119]. These stories create such space, where it is always possible for Good to triumph. *Bad* characters are always defeated by *good* or punished with the help of magic.

Thus, the system of personages is also used to show difference between *good* and *bad*. Characters may be entirely fictional, or they may be based upon real entities, contemporary or historical. They may be human, supernatural, mythical, divine, animal or personifications of an abstraction [4, p. 66–68]. The characteristic feature of contemporary fairy tales is that *bad* personages can become *not bad* (they will never become *good*), while *good* characters can only improve their positive qualities.

In accordance to *good/bad* criterion, all characters of literary fairy tales are divided into 3 groups: 1) those who cause Evil; 2) those who suffer from Evil; 3) those who create Good and fight against Evil [4, p. 113].

1) *Those who cause Evil* are always negative personages. The most popular characters include trolls, giants, Baba Yaga, Koschei, man-eater, stepmother, and evil master. These images can be realistic, allegoric and fantastic.

2) *Those who suffer from Evil* perform the victim part. They can either be passive, waiting till somebody helps them, or active, resisting Bad themselves, but still lacking strength to overcome it.

3) *Those who create Good and fight against Evil* are always positive personages. They are usually magicians, warriors, and their assistants: brides, prophets, domestic and wild animals. Images of good animals-helpers are derivative from folk fairy tales and from traditional belief in animals' sancrity. Human positive personages often reflect their one or two greatest virtues, for example physical strength, mental abilities, practical skills, which are usually hyperbolised (exaggerated) [ibid.].

In the course of our research we have found out that V. Y. Propp's classification of fairy tale personages types, although is based on the dominant functions of characters and their place in plot development, still reflects traditional division in the team of *good* and the team of *bad* [7, p. 95–99]. There are only 3 negative character types among 7 of them.

The protagonist of the fairy tale is always the main character. He or quite often she is the one without whom there would be no story, as he/she in the centre of author's attention and the one who moves the plot. What is more, the hero or victim/seeker hero is a central positive personage who units others from the team of *good*. This character reacts to the donor and weds the princess as a reward.

According to V. Propp, other *good* fairy tale personages are subordinate to the hero. They either help the main positive personage or are those in favour of whom the *hero* acts. Among them, we should mention *the princess*, who is often sought for during the narrative and usually marries the hero at the end of the story; and *the princess' father*, who gives the task to the hero and identifies the false hero.

Although the princess and her father are usually shown together, functionally, the princess and the father cannot be clearly distinguished [7]. Their functional role in contemporary fairy tales often changes from passive into active, especially if consider princess. From the feministic perspective, she cannot only acquire the right to speak and have her own position, but also becomes participant of many events in fairy tale.

Other *good* characters are represented by *the donor*, who prepares the hero or gives them a magical object; *the (magical) helper*, who helps the hero in the quest.

The most prominent character against whom the protagonist struggles is antagonist. He/she/it is always a negative personage, and according to V. Y. Propp [7], is called *the villain*. Representing *bad* in contemporary fairy tales, the villain is often personified, though, in case if it is a collective Evil, it is not so distinguishable. The actions that fall into a villain's sphere are as follows: 1) a story-initiating villainy, where the villain caused harm to the hero or his family; 2) a conflict between the hero and the villain, either a fight or other competition; 3) pursuing the hero after he has succeeded in winning the fight or obtaining something from the villain.

None of these acts necessarily occurs in a fairy tale, but when any of them do, the character that performs the act is the villain. The villain therefore can appear twice: once in the opening of the story, and a second time as the person sought out by the hero. When a character performs only these acts, the character is a pure villain [4, p. 210–213]. Various villains also perform other functions in a fairy tale; a witch who fought the hero and ran away, and who lets the hero follow her, is also performing the task of "guidance" and thus acting as a helper.

The functions can also be spread out among several characters. If a dragon acts as the villain, but is killed by the hero, another character (such as the dragon's sisters) might take on the role of the villain and pursue the hero.

Two other characters could appear in roles that are villainous in the more general sense. One is the *false hero*. He is the one who takes credit for the hero's actions or tries to marry the princess. This character is always villainous, presenting a false claim to be the hero that must be rebutted for the happy ending [3]. His actions are dispraised. Among such female characters are stepsisters, who pretend to be beautiful princesses instead of poor "Cinderella" girl.

Another character, *the dispatcher*, sends a hero on his quest [1, p. 95–99]. This might be an innocent request, to fulfil a legitimate need, but the dispatcher might also, villainously, lie to send a character on a quest in hopes of being rid of him. So, the dispatcher is the character who makes the lack known and sends the hero off.

All in all, personages of contemporary English and Ukrainian literary fairy tales are used to show difference between *good* and *bad*. *Good* characters are opposed to *bad* in their appearance, social status and deeds. According to the unwritten fairy tale rule, it is common that *good* personages leaded by the hero always win in the end. They are praised and rewarded because they are good protectors of moral virtues and social values. Thus, the opposition of *good* and *bad* in contemporary fairy tales usually ends up with the victory of *good*, although sometimes the story can have an open ending, when small victory over *bad* allows hero fight against Evil in the fairy tale sequels.

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# Improvement of Psychology and Pedagogical Process on Physical Training

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***Abstract***

The overall performance of the teacher of physical culture substantially depends on presence at them of psychological knowledge and abilities. The practical success in the solution of pedagogical problems of education of harmoniously developed creative person depends on the level of their psychological literacy.
The most important conditions of improvement of psychology and pedagogical process is accurate understanding of the purpose of joint activity of the pupil and teacher, its transfer to the principles of democratization and humanization. Ideas for reconstructing of pedagogical process on the basis of cooperation pedagogics are presented. The key role for development of theoretical and methodical fundamentals of psychology of physical training is played by the pedagogical psychology studying psychological problems of training and education, those conditions of pedagogical process which create the maximum developing effect of training.

**Keywords:** physical training, physical culture, pedagogical process, psychological knowledge

Psychological knowledge strongly was part of necessary theoretical training of specialists on physical culture, sport and tourism. The overall performance of the teacher of physical culture, the trainer substantially depends on presence at them of psychological knowledge and abilities. To organize training process to the trainer, process of physical training to the teacher of physical culture, it is impossible to provide successful performance of the athletes at competitions without knowledge of psychological regularities in behavior of the person in various situations. All this speaks about need of systematic studying of psychology as important subject for the experts working with people.

In focus of attention of psychology of physical training psychological regularities of formation of the personality are in process of physical education and sports activities. Experts of this profile represent mass and popular profession in modern society. The practical success in the solution of pedagogical problems of education of harmoniously developed creative person depends on the level of their psychological literacy.

Training of experts and students in fundamentals of psychology of physical training demands more accurate psychology and pedagogical orientation. Existence of difficulties in development of psychology of physical training, in development of theoretical and experimental bases of this cross-disciplinary branch of pedagogical psychology requires close and close attention to it.

The psychology of physical training has own subject domain of researches of mentality of the person as persons. The understanding of the person as subject of the motive, physical, motor activity presented at all levels of the mental organization of the personality and included in all vital manifestations of people is initial. As the subject of psychology of physical training is refraction of psychological knowledge specifically to activity of the teacher of physical culture and the trainer by the form sport solving problems of education and formation of the personality means of physical culture.

The most important conditions of improvement of psychology and pedagogical process is accurate understanding of the purpose of joint activity of the pupil and teacher, its transfer to the principles of democratization and humanization. According to these principles reorientation of teaching and educational process from reproduction of examples of ready knowledge, motive skills on formation at children and teenagers of conscious need for physical improvement and education of habits to healthy lifestyle is necessary. For this purpose educational process has to be sated first of all with data from area of personal and social hygiene, physiology, psychology, the theory and technique of physical training which form evidence-based views of social and biological essence, of role and possibilities of physical culture in development of the person. In this sense studies on physical culture have to turn gradually into lessons of knowledge of, the organism, the moral and strong-willed qualities, spiritual and physical capacities.

Saturation of teaching and educational process by big variety of educational and methodical material, use of various forms, methods and the organizations of the educational and out-of-class work considering regional, national traditions, modern sports fashion, the interests of the specific pupil is not less important.

Reconstructing pedagogical process on the basis of cooperation pedagogics, it is necessary to be guided by its leading positions (ideas):

- exception of methods of coercion to the doctrine and application only of such methods which include children in the general process of mastering physical culture, cause the joy of occupations and of achievement of result, contribute to forward motion and the development;

- the "difficult purpose" providing gradual development of strong-willed qualities, personal responsibility, belief in possibility of overcoming difficulty;

- the "support" allowing any pupil to progress consistently in the doctrine;

- the "advancing" consisting in the accelerated development strong, the most capable in this type of motive activities (physical exercises) of pupils;

- "large blocks" which allow to acquire the main intrinsic concepts, communications, to seize "systems" of means and methods of physical culture that promotes increase in volume of the mastered material and reduces loads of the pupil;

- "introspection", the commonwealth with parents;

- control forms, new approaches to gain score which are focused on the doctrine without coercion. As shows the best pedagogical and foreign practices, for the successful solution of the tasks connected with education of habit of healthy lifestyle, two physical education classes in week insufficiently. The third lesson is required. Since the main school, two-three lessons in quarter have to be devoted to formation of profound knowledge in the field of valueology and to use of this knowledge in everyday life.

In the light of the developed ideas of reorganization of teaching and educational process on physical training it is more preferable to use quality indicators of achievements of pupils: quality of mastering the program material including theoretical and methodical knowledge, movement skills and abilities, ways of recreational and sports activity. The special attention has to be deserved activity of pupils on classes in physical culture, ability to lead healthy lifestyle. At assessment of achievements of especially weak pupils in the physical relation it is necessary to be guided by rates of advance of results in development of their motor abilities to a large extent.

As a result it has to become source of positive emotional experiences, will lead to formation of requirement and desire to be engaged in physical exercises, and maintaining healthy lifestyle will gain personal sense.

Approach to theoretical fundamentals of psychology of physical training proceeds from understanding of integrity and the continuity of process of formation and development of the person as persons, from the provision on unity of her consciousness and activity, dialectic communication of processes of intellectual and physical maturing of the person as individual in all variety of its individual and typical properties formed and realized in close connection with conditions of activity and by means of it.

The key role for development of theoretical and methodical fundamentals of psychology of physical training is played by the pedagogical psychology studying psychological problems of training and education, those conditions of pedagogical process which create the maximum developing effect of training.

One of the main objectives of reorganization of physical training of children and teenagers – updating and expansion of scope of the basic and applied pedagogical, psychological, biological, medical, sociological and cross-disciplinary re-searches reflecting relevant and perspective requirements of physical culture and healthy lifestyle of children and teenagers taking into account regional and national specifics of work.

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# Classification of Principles of Education and Teaching Learning Process in Ukrainian Didactics in the XX$^{th}$ – the beginning of the XXI$^{st}$ Century: Attempt of Retro Analysis

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***Abstract***

The article is investigated the contribution of Ukrainian scientists in didactics in the XX$^{th}$ – the beginning of the XXI$^{st}$ century, who identified the bases of the initial principles of the substantiation of the essence the concept "the principles of teaching" and developed approaches to their classifications. The classifications of teaching principles by M.Bogdanovich, O.Savchenko, B.Korotyaev, V.Onyshchuk, V.Palamarchuk, O.Padalka, A.Nisimchuk, I.Smolyuk, O.Shpak, V.Galuzinsky, M.Yevtukha, V.Yagupov, V.Bondar are analyzed. The author presents some factors of classification and describes a modern classification for teaching principles (methodological, scientific, psychological, pedagogical, didactical). The list of general-didactic principles is given.

**Key word**s: didactics, concept, principle, classification, methodological principles of teaching, scientific principles of teaching, psychological principles of teaching, pedagogical principles of teaching, didactic principles.

***Актуальність дослідження***. Однією з найважливіших категорій дидактики є дидактичні принципи, які, незважаючи на історичну давність поняття, й до нині не приведені в єдину наукову систему. Тому у сучасній дидактиці в умовах докорінної перебудови шкільної освіти окреслюється ряд малодосліджених аспектів проблеми вивчення принципів навчання. Серед них особливо важливими є наступні: невизначеність змісту та сутності принципів навчання; конкретизація новітніх принципів навчання, які відображають вимоги суспільства до освіти; недостатня обґрунтованість наукової основи системи принципів навчання, їх підпорядкованості, ієрархії [10; 11; 18; 19; 23; 24].

Тому закономірно, що в посібниках з педагогіки та дидактики кількість, ієрархія та формулювання принципів навчання представлені досить по-різному.

Така різноплановість у підходах до обґрунтування сутності й характерних ознак, створення системи і втілення в практику навчання дидактичних принципів обумовила необхідність вивчення доробку вітчизняних педагогів та дидактів (А.Алексюка, В.Бондаря, Г.Ващенко, С.Гончаренка, Б.Коротяєва, В.Лозової, Н.Мойсеюк, В.Омельяненка, В.Онищука, В.Паламарчук, В.Помагайби, Г.Троцко, С.Русової, О.Савченко, В.Сухомлинського, С.Чавдарова, В.Ягупова та ін.) [11].

Значущими для нас виявилися й дослідження особливостей принципів навчання зарубіжними науковцями (Ю.Бабанським, М.Даниловим, А.Дістервегом, А.Єсиповим, А.Загвязінським, Я.Коменським, М.Корфом, І.Лернером, В.Оконем, М.Скаткіним та ін.). Крім того було проаналізовано класифікації дидактичних принципів українськими науковцями: М.Богдановичем, О.Савченко (1980), Б.Коротяєвим (1986), В.Онищуком, В.Паламарчук (1987), О.Падалкою, А.Нісімчуком, І.Смолюком, О.Шпаком (1995), В.Галузинським, М.Євтухом (1995), В.Ягуповим (2002) В.Бондарем (2005) та ін.

***Виклад основного матеріалу.*** Дидактичні принципи мають давню історію й пов'язані з виникненням та розвитком класно-урочної організації навчання і дидактики як науки.

Поняття *«принцип»* походить від латинського *«principит», що* означає початок, основа, підвалина.

Принципи навчання в науковому просторі визначають як: 1) «найбільш загальні вихідні положення, покладені в основу змісту, організації й проведення процесу навчання [8, с. 118]»; 2) «визначену систему вихідних, основних дидактичних вимог, установок до процесу навчання, виконання яких забезпечує ефективність практичної діяльності [14, с. 222]»; 3) «вихідні положення, що визначають різні сторони навчання – зміст, методи, засоби, форми. Структура дидактичних принципів обумовлена структурою законів і закономірностей навчання [7, с. 42-43]».

Наведені формулювання принципів навчання є теоретичними узагальненнями педагогічної практики певного періоду розвитку дидактики, які виникають із досвіду педагогічної діяльності, носять об'єктивний характер, обумовлюються законами і закономірностями навчання. Тому, І.Підласий зазначає, що в принципах зафіксовано тисячолітній досвід ефективної реалізації навчання й виховання, скорегований науковими дослідженнями та надбаннями передової шкільної практики [20, с. 440]. Через що, проведемо ретроспективний аналіз підходів учених до визначення принципів навчання.

Так, у «Великій дидактиці» Я.Коменського (1632) розглядаються шість принципів навчання: наочності, свідомості, систематичності, послідовності, доступності, міцності засвоєних знань [11].

Німецький педагог А.Дістервег (1790–1866), на основі виділених ним психологічних законів, визначив дидактичні принципи і правила у вигляді вимог до: 1) змісту навчання; 2) вчителя; 3) учня. Всього виокремив 33 правила.

У *таблиці 1* наведено короткий ретроспективний перелік принципів навчання у вітчизняних навчальних посібниках та підручниках з педагогіки та дидактики XX – поч. XXI ст.

*Таблиця 1*

**Принципів навчання у вітчизняній навчально-методичній літературі XX – поч. XXI ст.**

| Автор | Рік вид. | К-сть принципів | Перелік принципів навчання |
|---|---|---|---|
| Г. Ващенко [4, с. 10, 83] | 1928/ 1929 | 8 | *Принцип* науковості навчання;<br>*принцип* систематичності навчання;<br>*принцип* виховуючого навчання;<br>*принцип* життєвості;<br>*принцип* активності;<br>*принцип* природовідповідності;<br>*принцип* індивідуалізації;<br>*принцип* наочності |
| С.Чавдаров / за ред. С.Чавдаров [17, с. 119-129] | 1940 | 9 | *Принцип* виховуючого навчання;<br>*принцип* науковості;<br>*принцип* систематичності;<br>*принцип* свідомості й активності;<br>*принцип* зв’язку теорії з практикою у навчанні;<br>*принцип* наочності навчання;<br>*принцип* міцності засвоєння знань;<br>*принцип* визнання учителя основною фігурою у навчанні;<br>*принцип* врахування вікових та індивідуальних особливостей психічного і фізичного розвитку дітей |
| С.Збандуто [9, с.192-204] | 1965 | 8 | *Принцип* комуністичної ідейності;<br>*принцип* зв’язку навчання з життям, з продуктивною працею;<br>*принцип* свідомого навчання й творчої активності учнів;<br>*принцип* наочності;<br>*принцип* науковості навчання;<br>*принцип* систематичності і послідовності;<br>*принцип* міцності засвоєння матеріалу;<br>*принцип* доступності навчання |
| А.Алексюк, | 1986 | 10 | *Принцип* комуністичної ідейності навчання; |

| | | | |
|---|---|---|---|
| В.Помагайба / за ред. М.Ярмаченко [1, с. 138-160]. | | | *принцип* науковості навчання;<br>*принцип* доступності навчання у його зв'язку з *віковими* та індивідуальними особливостями учнів;<br>*принцип* активності, самостійності в навчанні при керівній ролі вчителя;<br>*принцип* систематичності навчання;<br>*принцип* свідомого засвоєння знань;<br>*принцип* зв'язку навчання з життям;<br>*принцип* наочності навчання;<br>*принцип* емоційності навчання;<br>*принцип* ґрунтовності навчання |
| С.Гончаренко [6, с. 270] | 1997 | 10 | *Принципи* зв'язку змісту і методів навчання з національною культурою і традиціями;<br>*принцип* виховуючого характеру навчання;<br>*принцип* науковості;<br>*принцип* систематичності;<br>*принцип* наступності;<br>*принцип* свідомості й активності учнів;<br>*принцип* наочності;<br>*принцип* доступності;<br>*принцип* індивідуалізації процесу навчання;<br>*принцип* уважного вивчення інтересів, здібностей, нахилів кожного учня |
| В.Лозова, Г.Троцко [14, с. 224-245]. | 2002 | 10 | *Принцип* виховуючого навчання;<br>*принцип* зв'язку навчання з життям;<br>*принцип* науковості освіти;<br>*принцип* трудності й доступності навчання;<br>*принцип* систематичності й системності в навчанні;<br>*принцип* активності й самостійності у навчанні;<br>*принцип* індивідуального підходу до учнів у навчанні;<br>*принцип* наочності навчання;<br>*принцип* міцності засвоєння знань, умінь і навичок;<br>*принцип* оптимізації навчального процесу |

Вивчивши дані таблиці 1, ми дійшли висновку, що:

1. Упродовж майже всього XX поч. XXI ст. дослідники рекомендували використовувати різну кількість принципів навчання.

2. Не існує загальновизнаної номенклатури принципів навчання.

3. Зміст співзвучних принципів навчання може мати різне тлумачення (наприклад, принцип системності й систематичності знань).

4. Часто принципи навчання розглядаються парами, що, з одного боку, вказує на взаємозв'язок головних положень дидактики, а з іншого – наповнює різним змістом визначені авторами принципи навчання.

Наступною проблемою є класифікація принципів навчання. В дидактиці ХХ – поч. ХХІ ст. утвердилося *кілька підходів до класифікації принципів навчання*, в основу яких було покладено: 1) досвід навчальної діяльності; 2) теорію пізнання; 3) закономірності функціонування психіки людини; 4) закономірності навчання) [22].

Тож, на початку 80-х років ХХ ст. М.Богданович і О.Савченко у статті «Проблема систематизації дидактичних принципів» запропонували систематизувати принципи *дидактики за ознакою їх цільового призначення відповідно до структури учіння як діяльності*. Такий підхід дозволив їм виділити **4 групи принципів**. *До першої* з них науковці віднесли *принципи соціалізації навчання*: 1) спрямованість навчання на всебічний і гармонійний розвиток особистості; 2) зв'язок навчання із суспільною свідомістю; 3) зв'язок навчання з продуктивною працею.

*До другої групи* М.Богданович і О.Савченко віднесли *принципи, які визначають зміст і систему навчання*: 1) відповідність змісту навчання теорії науки; 2) зв'язок та оптимальне співвідношення теорії та практики; 3) систематичність і послідовність навчання; 4) забезпечення міжпредметних зв'язків у навчанні; 5) доступність і своєчасність у навчанні.

*Третя група* об'єднувала принципи, дотримання яких сприяло оптимізації учіння й позитивно впливало на розвиток учнів у процесі навчання. Серед них принципи: 1) випереджаючого навчання; 2) мотиваційного навчання; 3) оптимального поєднання конкретного й абстрактного; 4) активності й розвитку пізнавальної самостійності у навчанні; 5) оптимального поєднання репродуктивних і пошукових методів навчання; 6) індивідуальності навчання.

Зауважимо, що автори не виокремлювали принцип наочності, вважаючи його не принципом, а лише одним із засобів забезпечення свідомості навчання.

*Четверту групу принципів*, за класифікацією науковців, становлять *принципи визначення результативності навчання*: 1) єдність освітніх і виховних результатів навчання; 2) міцність, свідомості та дієвості знань; 3) взаємозворотній зв'язок, 4) оптимальне поєднання контролю й самоконтролю у процесі навчання [2, с. 5 – 20].

У свою чергу, Б.Коротяєв у посібнику «Педагогіка як сукупність педагогічних теорій» (1986 р.) представив класифікацію принципів навчання відповідно до закономірних зв'язків і відношень між складовими сторонами, частинами та компонентами власного дидактичного об'єкта [10].

Вітчизняні дидактики В.Онищук та В.Паламарчук у посібнику для вчителів «Дидактика сучасної школи» (1987) в основу класифікації принципів навчання поклали ідею забезпечення єдності освітньої, виховної та розвивальної функцій навчання, а також чітко підкреслили, що структура дидактичних принципів обумовлена структурою законів і закономірностей навчання [7, с. 42–43].

У 90-х рр. вітчизняними науковцями та дидактами було запропоновано й інші варіанти класифікації принципів навчання. Автори навчального посібника «*Педагогічні технології*» О.Падалка, А.Нісімчук, І.Смолюк, О.Шпак поділяють принципи навчання на традиційні та нетрадиційні [16].

У навчальному посібнику «*Педагогіка: теорія та історія*» В.Галузинський, М.Євтух принципи навчання класифікують [5] *за трьома групами*: *перша* обслуговує компоненти процесу, *друга* – діяльність викладача і його методику викладання, *третя* – результативний компонент процесу навчання.

У навчальному посібнику В.Ягупова «Педагогіка» представлено 4 групи принципів навчання, які виражають вимоги до організації: 1) усіх компонентів дидактичного процесу; 2) діяльності суб'єктів викладання (вчителів) та їхньої методики; 3) навчально-пізнавальної діяльності суб'єктів учіння (учнів); 3) контрольно-оцінювальних функцій дидактичного процесу [22].

Звернемо увагу на те, що більша кількість класифікаційних ознак при конструюванні системи принципів навчання була врахована В.Бондарем («Дидактика», 2005): 1) *Принципи, що регулюють мету й завдання процесу навчання* (спрямованість навчання на здійснення завдань освіти, виховання й розвитку особистості дитини). 2) *Принципи, що забезпечують орієнтацію вчителя на особистість дитини* (активно-діяльнісний характер навчання; єдність мотиваційної сфери особистості; забезпечення успіху в оволодінні знаннями; розкриття здібностей й творчих задатків учнів; врахування їхніх вікових та індивідуальних особливостей). 3) *Принципи, що* *забезпечують орієнтацію учителя на добір змісту підручника і уроку* (науковість навчання, доступність і послідовність змісту, наочність навчання, зв'язок навчання з життям, виховного і розвиваючого навчання тощо). 4) *Принципи, що регулюють операційно-діяльнісний компонент процесу навчання* (наочності, свідомості й активності учнів за керівної ролі вчителя, поєднання різних методів, засобів і форм організації навчання). 5) *Принципи, що дають змогу оцінювати результативність навчання* (міцності знань, свідомості навчання, дієвості знань, виховуючого та розвиваючого навчання) [3, с. 146].

Отже, розглянувши різні класифікації принципів навчання, можна зробити висновок, що не існує будь-якої універсальної класифікації. На кожному етапі розвитку вітчизняної дидактики XX – поч. XXI ст. провідну роль у цьому питанні відігравали різні парадигмальні підходи (діяльнісний, системний тощо).

У свою чергу, розширення об'єкта і предмета сучасної дидактики дозволяє по-новому класифікувати принципи навчання. Так, сучасні принципи навчання можна об'єднати в такі групи: 1) *методологічні (філософські*), що відображають концептуальну стратегію освіти (принципи гуманізації, гуманітаризації, демократизації, зв'язку з життям, рівнем розвитку філософії освіти, антропоцентризму, культуровідповідності та ін.); 2) *наукові,* що стосуються наповнюваності змісту освіти, визначення мети й завдань процесу навчання (принцип науковості, систематичності, наступності та ін.) 3) *психологічні*, що стосуються організації навчально-пізнавальної діяльності суб’єктів учіння (індивідуалізації, мотивації навчально-пізнавальної діяльності учнів, активності, свідомості та самостійності у навчанні та ін.); 4) *педагогічні*, які виражають вимоги до діяльності викладача та методики його викладання (доступності, наочності, раціонального поєднання колективних та індивідуальних форм і способів навчальної роботи тощо); 5) *власне дидактичні* (міцності засвоєння знань, дієвості знань, виховуючого та розвиваючого навчання, формування навичок і умінь та ін).

Але наголосимо, що і запропонована класифікація не претендує на завершеність. Як зазначає В.Оконь, принципи навчання, їх класифікація – «це найбільш спірна галузь дидактики. В її межах існують вкрай протилежні думки, які часто суперечать одна одній» [15, с. 177].

**Висновки.** Підсумовуючи викладене вище, наприкінець згадаємо С.Чавдарова, який ще у 1940 р. писав: «На основі … принципів навчання мають бути розв’язані всі питання навчання в їх конкретній постановці: питання змісту навчання дітей різного віку, питання організаційних форм навчання, необхідних для нього навчально-виховних засобів (підручників, приладдя, навчального устаткування та ін.), питання методів викладання навчальних предметів» [17, с. 129].

Тому очевидно, що принципи не є дидактичною аксіомою, вони повинні оновлюватися, уточнюватися, розширюватися, доповнюватися під впливом досягнень вітчизняної та зарубіжної педагогічної науки.

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*Translation of the Title, Abstract and References to the Author's Language*

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**Кушнірук Світлана. Класифікація принципів навчання у вітчизняній дидактиці XX поч. XXI ст. : спроба ретроаналізу.**

У статті досліджено внесок українських науковців та дидактів XX – поч. XXI ст. у визначення вихідних засад обґрунтування сутності поняття «принципи навчання» та у розробку підходів до їх класифікації. Проаналізовано класифікації принципів навчання М.Богдановича, О.Савченко, Б.Коротяєва, В.Онищука, В.Паламарчук, О.Падалки, А.Нісімчука, І.Смолюка, О.Шпака, В.Галузинського, М.Євтуха, В. Ягупова, В.Бондаря. Визначено класифікаційні чинники та запропоновано сучасну класифікацію принципів навчання (методологічні; наукові; психологічні; педагогічні, власне дидактичні). Наведено перелік загальнодидактичних принципів.

**Ключові слова:** дидактика, поняття, принцип, класифікація, методологічні принципи навчання, наукові принципи навчання, психологічні принципи навчання, педагогічні принципи навчання, власне дидактичні принципи.

**Кушнирук Светлана. Классификация принципов обучения в отечественной дидактике XX нач. XXI в .: попытка ретроанализа.**

В статье исследован вклад украинских ученых и дидактов XX - нач. XXI в. в определение исходных принципов обоснования сущности понятия «принципы обучения» и в разработку подходов к их классификации. Проанализированы классификации принципов обучения М.Богдановича, А.Савченко, Б.Коротяева, В.Онищука, В.Паламарчук, О.Падалки, А.Нисимчука, И.Смолюка, А.Шпака, В.Галузинского, Н.Евтуха, В. Ягупова, В.Бондаря. Определены классификационные факторы и предложено современную классификацию принципов обучения (методологические; научные, психологические; педагогические, собственно дидактические). Приведен перечень общедидактических принципов.

**Ключевые слова:** дидактика, понятие, принцип, классификация, методологические принципы обучения, научные принципы обучения, психологические принципы обучения, педагогические принципы обучения, собственно дидактические принципы.

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# Methodological Means of Forming Performance Skills in Teacher-Violinist in the Process of Professional Preparation

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***Abstract***

The article deals with the methodological support of the process aimed at developing the performing skills in future violin teachers in conditions of special training. Scientific approaches are justified: competence, which facilitates the formation of technical-coordination, program-repertoire, interpretation, concert-performing competencies; synergetic, which allows to consider the process of special education from the standpoint of openness and organization to self-development; individual, which includes projective, research, discursive ways of organizing educational activity; taxonomic, which makes the process of instrumental-performance preparation purposeful, dynamic and mobile. The study developed the principles (active-information influence, artistic and technical unity while subordinating to technical art), as well as pedagogical conditions: creating an artistic and creative atmosphere in the violin class; concentration of attention to the reflection of mental feelings that accompany the development of performing techniques; orientation on polyfunctional strategy of performing activity in a future teacher-violinist; activation of independent work on the violin on the basis of the acquired knowledge and experience of their application; creation of success situations in the process of improving the performance of students. The proposed methodological foundations contribute to the effective formation of the performing skills in future violin teachers and give methods to improve personal and professional skills.

**Keywords:** violin teacher, performing skills, special training, methodological support.

***Актуальність дослідження.*** На сьогоднішній день у різних країнах світу особливої значущості набуває проблема підготовки фахівців музичного мистецтва, зокрема майбутніх педагогів-скрипалів. Скрипка належить до найбільш популярних музичних інструментів, тому попит на нові методики навчання у цій галузі інструментального виконавства постійно зростає.

Вивчення методичних праць видатних музикантів-скрипалів дозволяє зробити висновок, що всі вони приділяли багато уваги різним аспектам удосконалення виконавської майстерності. Так, методичні принципи представників скрипкових шкіл (Б.Струве, Ю.Янкелевича, А.Ямпольського, Л.Ауера, К.Флеша, К.Мостраса, В.Григор'єва, І.Войку, В.П'ятигорського, О.Шульпякова, Ф.Штейнгауза та багато інших) залишаються золотим фондом скрипкової педагогіки. Запропоновані ними методичні поради щодо удосконалення виконавських умінь скрипалів становлять великий інтерес як для вчених-дослідників, так і для викладачів-практиків.

Разом з тим, високі вимоги до якості виконавської підготовки майбутніх педагогів-скрипалів зумовлюють необхідність розробки нових методологічних засад, на яких ґрунтується сучасна методика навчання гри на скрипці. До них ми відносимо наукові підходи, принципи і педагогічні умови, які забезпечують розробку нових методичних засобів навчання.

***Виклад основного матеріалу.*** Завдяки науковим розвідкам нами було встановлено, що необхідність збагачення виконавського досвіду і ефективного виконання викладацьких функцій студентів музично-педагогічних закладів актуалізує важливість застосування компетентнісного підходу [5; 13; 14]. Його сутність полягає в інтеграції змісту і технологій під час осягнення навчального матеріалу, що сприяє формуванню необхідних компетенцій, а саме:

– *техніко-координаційними* (сформованість техніки гри на скрипці, яка передбачає координацію функцій рук та раціональність рухів, точність звуковисотної інтонації, володіння різними аплікатурними прийомами і штрихами, технікою звуковедення, метроритмічну чіткість, сформованість аналітико-слухових навичок, здатність до самоаналізу і самовдосконалення). Ця компетентність об'єднує галузь виконавських і методичних умінь і навичок, необхідних майбутньому фахівцю для успішного здійснення своїх професійних обов'язків. Вона передбачає наявність особистого творчо-виконавського досвіду, вміння роз'ясняти і тлумачити музичні явища, а також організовувати навчальний процес;

– *програмно-репертуарними* (знання скрипкового та оркестрового репертуару, здатність самостійно його підбирати для уроків з учнями різних вікових категорій; уміння здійснювати історично-теоретичний, цілісно-методичний, художньо-педагогічний і техніко-виконавський аналіз музичних творів). Очевидним є те, що основу цієї компетентності складають фахові знання. Більшість учених під знаннями розуміють форму існування і систематизацію результатів певного кола відомостей. Знання необхідні педагогу-скрипалю для раціональної організації своєї педагогічної діяльності й подолання проблем, які виникають у її процесі; вони стають невід'ємною частиною професійного образу компетентного фахівця.

– *інтерпретаційними* (здатність до виконавської інтерпретації музичних творів, зокрема дотримання авторського задуму композитора, форми та стилю твору;

можливість розкривати художні образи різних творів за допомогою досконалої техніки та застосування різноманітних засобів виразності – динаміки, агогіки, тембрового забарвлення, логічного фразування). Ця компетентність ґрунтується на особистісному ставленні до музичних творів, здатності оцінювати своє виконання і свою педагогічну діяльність. Вона спрямовує формування інструментально-виконавської компетентності педагога-музиканта на педагогічну діяльність;

– *концертно-виконавськими* (готовність до виконавської та музично-просвітницької діяльності, сформованість сценічної культури, артистизм, творчий імідж, уміння організовувати концертну діяльність своїх учнів).

Відповідно ми розглядаємо компетентність в галузі музично-педагогічної освіти як особистісну характеристику і свідому діяльність, спрямовану на повне виявлення і розвиток власних виконавських можливостей у педагогічному просторі. Такий ракурс навчально-виконавської діяльності дозволяє майбутньому педагогу-скрипалю успішно розв'язувати професійній завдання і швидко адаптуватися на ринку праці. Врахування особливостей компетентнісного підходу дозволяє не тільки набути певної майстерності в уміннях і навичках, а й у спрямовуванні студентів на організацію художньо-пізнавального та музично-виконавського процесів, вміння створювати художньо-творче середовище й комунікативні ситуації в навчально-виховному процесі [8; 9; 10; 11].

Застосування синергетичного підходу в музично-педагогічній освіті надає можливість розглядати процес фахового навчання з позицій відкритості та орієнтації на саморозвиток. Такий навчальний вибір дозволяє визначити індивідуальну траєкторію освіти, темп навчання, досягнути вищого рівня освіченості, обирати типи навчальних закладів, навчальні дисципліни і викладачів, форми і методи навчання, творчі завдання тощо. Отже, сутність синергетичного підходу для фахової підготовки майбутніх педагогів-скрипалів полягає у виявленні загальних закономірностей, що керують процесами самоорганізації суб'єктів навчально-виховного процесу у вищому навчальному закладі [12].

Для фахової підготовки майбутнього педагога-скрипаля не менш важливим є застосування індивідуального підходу. Його сутність складає гнучке використання різноманітних форм і методів навчання студентів з метою досягнення оптимальних результатів стосовно кожного вихованця [4, с. 150]. У контексті нашого дослідження вважаємо індивідуальний підхід провідним, оскільки він має особливе значення для формування творчої особистості. Це зумовлено тим, що спілкування особистості з мистецтвом завжди є індивідуальним. Також за своєю сутністю індивідуальним є професійний розвиток творчих якостей майбутнього педагога-скрипаля.

Згідно висновків С.Сисоєвої, індивідуальний підхід має виняткове значення для формування творчої особистості. Його особливістю є врахування педагогом індивідуально-психологічних характеристик студентів, їхніх здібностей, ставлення до навчання. На цій основі у них найповніше розвиваються творчі можливості для навчання.

До того ж, характерною рисою індивідуального підходу є «особистісно-центроване» навчання (І.Бех), адже у центрованій на особистість освіті відбувається діалог повноправних суб'єктів взаємодії. Для такого навчання необхідно спрямувати спеціальні зусилля, аби зв'язати навчальний матеріал з досвідом студента, стимулювати його інтерес до тих проблем, які знаходяться у центрі уваги митців. На думку О.Щолокової, в особистісно-центрованій музичній освіті відбувається узгодження та взаємодія її спонтанної та упорядкованої складових, які ґрунтуються на проективних, дослідницьких, дискурсивних способах організації навчальної діяльності [12].

Різновидом такого підходу можна вважати художньо-персоналізований підхід, запроваджений у дисертаційному дослідженні О.Андрейко. За визначенням автора, його дія забезпечує інтеграцію індивідуально духовної, соціальної і художньо-технологічної складових навчального процесу як основи художнього становлення скрипаля і спрямована на активізацію процесів інтеріоризації об'єктивних взаємовідносин (композитор – твір – виконавець) в інтрасуб'єктивні психічні властивості виконавця, викликаючи розвиток якісно нових індивідуальних виконавських характеристик і спонукаючи студента до естетично-творчої самореалізації [1].

Ціннім для нашого дослідження є й включення у систему виконавської підготовки студентів таксономічного підходу. У дисертаційному дослідженні Н.Мозгальової було виявлено, що за його допомогою у навчальному процесі можна коригувати цілі і завдання, проводити експериментальну перевірку ідей, аналізувати варіанти управлінських рішень, розробляти нові прогностичні моделі та методики навчання, створювати оптимальні умови для набуття високого рівня готовності майбутніх педагогів-музикантів до виконавської діяльності.

На думку дослідниці, таксономічний підхід до інструментально-виконавської підготовки виступає теоретичною основою узгодженості соціальних (зафіксованих у нормативних документах), особистісних (орієнтованих на потреби та очікування студентів) та педагогічних ( визначених викладачами стосовно фахових дисциплін і навчальних занять) цілей, що робить процес інструментально-виконавської підготовки цілеспрямованим, динамічним, дієвим, адекватним та мобільним для сучасних потреб вищої школи у високоосвічених і кваліфікованих педагогах-музикантах, здатних досягнути успіху в майбутній професійній діяльності [6].

Для керівництва процесом формування виконавських умінь майбутнього педагога-музиканта викладачі вищих навчальних закладів мають оволодіти принципами навчання, які виступають керівною ідеєю, нормами і правилами діяльності. У цьому контексті Г.Падалка зазначає, що принципи мистецького навчання – це основні положення, які визначають сутність, зміст, провідні вимоги до взаємодії вчителя і учнів. Серед найголовніших дослідниця визначає такі принципи опанування мистецтва: цілісності; культуровідповідності; естетичної спрямованості; індивідуалізації; рефлексії. [7, с. 149–159].

Разом з тим, у наукових дослідженнях за останнє десятиліття обґрунтовано і впроваджено ряд спеціальних принципів, спрямованих на оптимізацію навчально-виховного процесу та підвищення якості підготовки фахівців у галузі мистецтва. Так, на наш погляд, перспективним у галузі формування інструментально-виконавських умінь майбутніх педагогів-скрипалів можна вважати застосування принципу активно-інформативного впливу на студентів, який передбачає накопичення мистецької, педагогічної й науково-практичної інформації в єдності з оволодінням майбутніми педагогами знань та умінь інформаційного характеру, зокрема умінь орієнтуватися в новому музично-інформаційному просторі.

Впровадження цього принципу вимагає включення студентів у пізнавально-пошукову та аналітичну діяльність, в якій розвиваються навчально-пізнавальні мотиви. Вони пов'язані з потребою у засвоєнні відповідних знань та узагальнених способів виконавських дій. У процесі фахової підготовки музикантів-скрипалів впровадження даного принципу передбачає усвідомлення студентами взаємозв'язку між змістом музичного твору, науковою і мистецькою інформацією; орієнтацію на самостійне ознайомлення з новими музичними творами та відповідною музикознавчою літературою, визначенням раціональних способів доведення отриманої інформації до слухачів [6, с. 13].

Суттєвими ознаками реалізації даного принципу є критичне ставлення студентів до змісту навчальної інформації. Активізація мислення студентів з опорою на розвиток їх критично-аналітичної оцінки та інтерпретації отриманої інформації ґрунтується на оптимальному поєднанні процесів музичного сприйняття і музичного пізнання з трансформацією практичного оволодіння прийомами діяльності. У цьому контексті особливого значення набуває оволодіння студентами рядом послідовних і взаємопов'язаних оцінних та аналітичних дій.

Професійно орієнтованого значення набувають принципи, які були розроблені й обґрунтовані в дисертаційних роботах українськими науковцями. Вони теоретично обґрунтовують зміст і послідовність реалізації системи взаємоузгоджених педагогічних цілей, враховуючи специфіку виконавської діяльності педагога-музиканта (Н.Мозгальова); визначають основні напрями навчання магістрів музичного мистецтва (О.Еременко); орієнтують на досягнення майбутніми вчителями музики фахової майстерності (А.Козир) та високого рівня професіоналізму (Н.Сегеда) тощо. Для удосконалення виконавських умінь педагога-скрипаля вважаємо також важливим принцип єдності художнього і технічного при підпорядкуванні технічного художньому. Його реалізація залежить від використання художнього потенціалу самої музики, засобів її мови, різноманіття елементів і стильових особливостей.

З урахуванням виділених у нашому дослідженні наукових підходів і педагогічних принципів у нашому дослідженні були розроблені педагогічні умови, спрямовані на формуванні виконавських умінь майбутніх педагогів-скрипалів. У даному контексті вони розглядаються як цілеспрямовано створені обставини мистецького навчання, що забезпечують можливість досягнення його результативності. На наш погляд, у процесі фахової підготовки студентів педагогічні умови повинні враховувати їх інтереси та уподобання і разом з тим сприяти музично-виконавському та художньо-естетичному розвитку.

*До таких педагогічних умов* ми відносимо: 1) створення художньо-творчої атмосфери занять у класі скрипки; 2) зосередженість уваги на рефлексії психічних відчуттів, які супроводжують розвиток виконавської техніки; 3) орієнтація на поліфункціональну стратегію виконавської діяльності майбутнього педагога-скрипаля; 4) активізація самостійної роботи над виконавським апаратом на основі отриманих знань і досвіду їх застосування; 5) створення ситуацій успіху в процесі удосконалення виконавських умінь студентів.

*Перша педагогічна умова* передбачає створення художньо-творчої атмосфери занять у процесі інструментальної підготовки педагога-скрипаля. На нашу думку, це одна з головних умов мистецького навчання загалом, яка має першочергове значення у фаховому навчанні студентів. Дотримання цієї умови орієнтує на інтенсифікацію музично-естетичних і творчо-діяльнісних чинників, які сприяють утворенню власної системи цінностей студента, формують його мотивацію до професійного зростання, виявляють індивідуальні якості. Відповідно до них відбувається творче опанування музичного матеріалу крізь призму власного відчуття його виконавської інтерпретації.

Ця умова реалізується на ґрунті індивідуального підходу й передбачає дотримання принципу активно-інформаційного впливу на студента, орієнтує на розвиток його творчого потенціалу, передбачає спрямованість навчального процесу на самопізнання й самореалізацію, що забезпечує дію внутрішніх механізмів формування особистісних якостей майбутнього педагога-музиканта, активність пізнавальної діяльності у вивченні музичних творів. Створення художньо-творчої атмосфери занять у процесі інструментальної підготовки студентів є особливо важливим для формування мотиваційного компоненту виконавської компетентності майбутнього вчителя музики.

*Друга педагогічна умова* пов'язана з розвитком рефлексії у виконавській діяльності скрипаля. Зазначимо, що у педагогіці рефлексія визначається як здатність до самопізнання та саморозвитку. Методи рефлексії найбільш ефективно забезпечують інструментальну підготовку майбутніх педагогів-скрипалів. Це зумовлено тим, що реалізація механізму рефлексії заснована на постійному самоаналізі, сприяючи підвищенню якісного рівня виконавської майстерності майбутніх фахівців. Механізм рефлексивного усвідомлення музично-виконавської діяльності є одним із найбільш важливих в інструментальній підготовці фахівців, оскільки стає поштовхом для їх пізнавальної та професійної активності [7, с. 88]. Таким чином, рефлексія виявляє процеси, які впливають на формування самоконтролю, а саме: самоспостереження, самооцінку і самоаналіз. Слухове самоспостереження є обов'язковою складовою інструментального виконавства, Саме тому, вбачаючи в ньому джерело прогресу для виконавського розвитку, видатний педагог Л. Ауер закликав своїх учнів «культивувати звичку до самоспостереження» [2, с. 44]. Отже, застосування механізмів рефлексії дозволяє полегшити усвідомлення завдань і звести вивчення твору до рівня його повного розуміння студентом на основі музично-виконавського самоконтролю.

Відповідно *до третьої педагогічної умови* розглядаємо можливість формувати виконавські уміння майбутніх педагогів-скрипалів у різних видах інструментальної діяльності. Основними завданнями на цьому етапі навчання ми визначили:

– опанування студентами техніки гра на музичному інструменті, яка передбачає засвоєння різноманітних вправ, етюдів і творів різних форм, стилів і жанрів, оволодіння виконавською постановкою, аплікатурними прийомами, штриховою технікою, звуковеденням, виконавською інтонацією, різноманітними прийомами фразування, агогіки, метроритму, поглибленого слухового контролю;

– оволодіння інтерпретаційними уміннями (реалізація авторського задуму в процесі виконання твору, створення художнього образу та варіативність його відтворення відповідно до різних ситуацій), використання широкої палітри засобів художньої виразності, дотримання форми, стилю і жанру твору;

– удосконалення виконавського репертуару та методів роботи з ним (етюдами, вправами, поліфонічними творами і творами великої форми, різними за характером п'єсами);

– формування виконавської і сценічної культури студентів (урахування індивідуальних особливостей, психологічна установка на публічний виступ, сценічна поведінка тощо).

*Четверта педагогічна умова* спрямована на активізацію самостійної роботи над виконавським апаратом на основі отриманих знань і досвіду їх застосування в процесі навчання. Реалізація на практиці цієї умови передбачає урахування положення, що пізнання музичного мистецтва та відтворення музичних творів на належному технічному рівні відбувається через моделювання творчого процесу. Формування самостійного музичного мислення студентів тісно зв'язане з розвитком усвідомленого сприймання музики, осмисленості та виразності у виконанні скрипкового репертуару. В даному випадку важливим фактором стає застосування елементів цілісного аналізу, розкриття музично-образного змісту твору в єдності з його формою. Цьому також допомагають знання стосовно музичних жанрів, стилів, відомості щодо творчості різних композиторів та скрипалів-виконавців. В цілому вони відіграють величезну роль у формуванні музичної творчості студентів та удосконаленні їх виконавської майстерності.

*Наступною педагогічною умовою* вважаємо створення ситуацій успіху в музично-виконавській діяльності студентів. Варто зазначити, що актуалізація проблеми досягнення успіху є надзвичайно важливою для сучасної практики інструментальної підготовки педагогів-музикантів, адже успіх, пережитий неодноразово під час навчання, сприяє визволенню прихованих потенційних можливостей студентів, перетворенню та реалізації їх духовних сил, стимулює до фахового саморозвитку й зростання.

Почуття успіху відіграє ключову роль у виконавському розвитку музиканта, оскільки воно лежить в основі всіх видів його діяльності й безпосередньо пов'язане з його природною активністю. Усвідомлення успіху, розуміння його важливості для себе, отримання емоційного піднесення, обумовлено внутрішнім світом самого студента і виникає внаслідок досягнення значущих для нього видах діяльності. Відповідно можна говорити про пряму залежність між почуттям успіху суб'єкта та мотивацією на його досягнення.

**Висновки.** Отже, формування виконавських умінь педагога-скрипаля є комплексним поняттям, яке відбувається у процесі навчання та здійснюється під впливом багатьох чинників: психічних, музично-досвідних, індивідуально-творчих. Необхідним середовищем для нього стає комплекс запропонованих методологічних засад, які сприяють ефективності здобуття студентом відповідних умінь й професійної майстерності.

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*Translation of the Title, Abstract and References to the Author's Language*

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**Радван Нассіб, Щолокова О.П. Методологічні засади формування виконавських умінь педагога-скрипаля у процесі фахової підготовки.**

У статті розглядаються питання методологічного забезпечення процесу, спрямованого на розвиток виконавських умінь майбутніх педагогів-скрипалів в умовах фахової підготовки. Обґрунтовуються наукові підходи: компетентнісний, який сприяє формуванню техніко-координаційних, програмно-репертуарних, інтерпретаційних, концертно-виконавських компетенцій; синергетичний, який надає можливість розглядати процес фахового навчання з позицій відкритості та орієнтації на

саморозвиток; індивідуальний, що ґрунтуються на проективних, дослідницьких, дискурсивних способах організації навчальної діяльності; таксономічний, котрий робить процес інструментально-виконавської підготовки цілеспрямованим, динамічним і мобільним. У дослідженні розроблені принципи (активно-інформаційного впливу, єдності художнього і технічного при підпорядкуванні технічного художньому), а також педагогічні умови: створення художньо-творчої атмосфери занять у класі скрипки; зосередженість уваги на рефлексії психічних відчуттів, які супроводжують розвиток виконавської техніки; орієнтація на поліфункціональну стратегію виконавської діяльності майбутнього педагога-скрипаля; активізація самостійної роботи над виконавським апаратом на основі отриманих знань і досвіду їх застосування; створення ситуацій успіху в процесі удосконалення виконавських умінь студентів. Запропоновані методологічні засади сприяють ефективному формуванню виконавських умінь майбутніх педагогів-скрипалів й удосконаленню їх професійної майстерності.

**Ключові слова:** педагог-скрипаль, виконавські уміння, фахова підготовка, методологічне забезпечення.

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# The Features of Pupils' Music Development in Primary School

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***Abstract***

The article is devoted to the study of the essence and structure of the phenomenon of pupils' music development in primary school. On the basis of the analysis of psychological and pedagogical works, and the conclusions are made about the peculiarities of this phenomenon in the context of the general music education for pupils in primary school. The role of musical activity in the music development of primary school pupils is outlined. The basic forms and methods of musical activity of pupils at Music lessons are considered. Stressed that the Music art lessons do not often meet the requirements of humanistic, educational education. In school practice, they are often confined to acquiring knowledge, skills, not using the opportunities that include the lesson of musical ethnicity. There is an objective need for a deeper theoretical understanding and practical disclosure of the enormous and extraordinary importance of the developing potential of general musical education. The branch of music education appears to be a cell that has extremely wide opportunities for music development of a child. Prerequisites for this are the variety of musical activities and a wide range of personality characteristics that are influenced during musical classes.

**Key words:** music development, primary school, pupils, musical activity, Music lesson.

***Актуальність дослідження.*** Гуманістичні тенденції, що визначають шляхи розбудови сучасної системи шкільної освіти в Україні, зумовлюють пильну увагу педагогів до реалізації завдань розвитку дитини, однією із цілей якого є музичний розвиток молодших школярів. Музичний розвиток, на нашу думку, складне явище. Між його компонентами встановлюються різноманітні взаємозв'язки: між природними задатками і сформованими на їхній основі музичними здібностями; між внутрішніми процесами розвитку й досвідом, який передається дитині ззовні; між засвоєнням досвіду й розвитком, що відбувається при цьому. Таким чином, здійснюється поєднання різноманітних внутрішніх процесів і зовнішніх впливів на них. Врахування вікових особливостей допомагає встановити, які саме форми, засоби і види діяльності найефективніші для музичного розвитку дитини того чи іншого віку.

Проблеми музичної розвиненості молодших школярів є актуальні, адже сучасна педагогіка пов'язує значні сподівання з підсиленням ролі мистецьких дисциплін і культурного середовища у розвитку гармонійно розвиненої, творчої особистості. У цьому контексті галузь музичної освіти постає осередком, що має надзвичайно широкі можливості для музичного розвитку молодших школярів. Передумовами цього є розмаїття видів естетичної діяльності й широке коло особистісних характеристик, що зазнають впливу під час музичних занять [4; 5; 6; 11; 12; 13; 14; 15; 16].

Уроки музичного мистецтва дуже часто не задовольняють вимоги гуманістичної, розвивальної освіти. У шкільній практиці вони нерідко обмежуються лише набуттям знань, умінь і навичок, не використовуючи тих можливостей, які містить урок музичного мистецтва. Отже, є об'єктивні потреби в більш глибокому теоретичному розумінні та практичному розкритті величезного й непересічного за значенням розвивального потенціалу загальної музичної освіти.

Значний внесок у розбудову розвивальних аспектів музичної освіти зробили В.Верховинець, Ф.Колесса, С.Людкевич, К.Стеценко, традиції яких розвинені в працях провідних представників вітчизняної музичної педагогіки. Розвивально – творчі ідеї набули подальшої розбудови в працях із теорії та методики музичної освіти дітей (Л.Баренбойм, Н.Ветлугіна, К.Головська, Л.Дмитрієва, Л.Горюнова, Д.Кабалевський, Л.Паньків, Г.Рігіна, О.Ростовський, О.Рудницька, Ю.Цагарелі), пізніше – у дослідженнях творчої активності (В.Бабій, І.Гадалова, В.Лабунець, О.Лобова, В.Тушева), розвитку творчих здібностей (М.Алейніков, О.Борисова, В Рагозіна, О.Хижна) та ін.

Незважаючи на багатовікову історію, проблема музичної розвиненості молодших школярів не тільки не втратила актуальності, а й поставила низку нових питань для розв'язання данної проблеми.

**Виклад основного матеріалу.** Усі види діяльності на уроці об'єднує важливе завдання – розвиток здатності учнів глибоко сприймати і переживати емоційно-естетичний зміст музики, розуміти її зв'язок із життям, усвідомлювати образність і виразність музичного твору. Молодші школярі отримують з навколишнього життя значну кількість музичних вражень, але діти не спроможні самостійно розібратися в них.

Досліджуючи особливості музичної розвиненості молодших школярів, О.Ростовський зазначає, що в галузі відчуттів і сприйняття їх розвиток іде від найпростішого розрізнення найвиразніших, найяскравіших барв, форм, звуків до активнішого усвідомлення красивих, гармонійних сполучень, до диференціювання звуковисотних та ритмічних співвідношень у музиці, нюансів кольорової гами, різноманітності форм, поетичного співзвуччя [9, с. 216].

Враховуючи, що молодший шкільний вік є особливо перспективним у розвитку музичного сприймання, необхідна достатня навантаженість на пам'ять дітей. Вона створює запас вражень і знань, потрібних для формування інтересу до музики. Важливими завданнями у вихованні молодшого школяра засобами музичного мистецтва є: розвиток слуху, пам'яті, уяви, музично-ритмічного відчуття, вокальних навичок.

Ми наголошуємо, що навчання музики молодших школярів має бути цікавим і радісним. Діти приходять до школи з різною музичною підготовкою і різними музичними задатками. Але у всіх дітей є деякий досвід слухання інструментальної музики, співу пісень, бачення і виконання танців, крокування під музику тощо. Їм розповідають і читають однакові казки [7], книжки, вони переглядають одні й ті ж телепередачі для дітей, кінофільми і мультфільми, стикаються з різноманітними подібними життєвими ситуаціями. В процесі дослідження ми з'ясували, що запас художніх і життєвих вражень дітей хоча й відрізняється кількісно, але в якісному плані він приблизно однаковий у всіх. Так складається життєвий досвід дитини, близький життєвому досвіду інших дітей. Свого часу Д. Кабалевський зробив висновок про те, що в умовах загальноосвітньої школи в музично-виховній роботі слід виходити не із здібностей дітей і їх підготовки, а з їхнього життєвого досвіду [3, с. 206].

Спостерігаються значні відмінності в музичній розвиненості дітей залежно від їх індивідуальних особливостей. Одні з них «музичні» за всіма показниками, інші відрізняються своєрідним поєднанням окремих музичних здібностей. Так, здатність сприймати і переживати музику може поєднуватися з посередніми голосовими даними, добрий розвиток музичного слуху не завжди супроводжується схильністю до творчості. Одні діти можуть слухати музику не відволікаючись, інші навіть не уявляють, що це таке — спеціально слухати музику; деякі діти можуть чисто і виразно виконувати знайомі пісні, мають елементарні уявлення про музику, інші байдужі до неї, оскільки жили у несприятливих для цього умовах. Зрозуміло, що внаслідок цього можливості музичного розвитку дітей на уроках музики різні.

Ми встановили, що шкільні уроки музичного мистецтва мають величезний потенціал для  розвитку дитини, передумовами якого є: образна природа музики з притаманними їй властивостями безпосереднього впливу на психоемоційний стан людини; усвідомлення предмета вивчення – музичного мистецтва – як результату творчості композитора, виконавця тощо; живе та творче спілкування з мистецтвом у процесі сприймання, розуміння й усвідомлення художніх образів; активне залучення учнів до «творення» мистецького продукту в різних видах музикування та додаткових творчих видах музичноестетичної діяльності (вокальній та інструментальній імпровізації, музично-ритмічних рухах, «малюванні музики» тощо); використання на уроках елементів літературного, хореографічного, візуальних та інших мистецтв тощо. У цьому контексті фактично всі види музичної діяльності школярів можуть (і мають) бути творчо спрямовані.

В результаті нашого дослідження ми виокремили загальні риси музичної розвиненості, які властиві учням початкової школи:

1. Діти мають певний досвід спілкування з музикою, а також їх музична діяльність стає різноманітнішою. Виконання пісень і танців, утілення музично-ігрових образів у русі набуває виразності, що свідчить про змогу учнів передати своє ставлення до музики. У них з'являються улюблені пісні, танці, ігри, вони здатні навіть мотивувати свої музичні вподобання, оцінювати твори, виявляти художні інтереси. У дітей помітними стають вияви музичних здібностей, особливо в царині мелодійного слуху. Учні можуть впізнати знайому пісню, визначити не тільки характер музики, але й її настрій. У них поступово налагоджується вокально-слухова координація, диференціюються слухові відчуття - більшість дітей здатна розрізнити високі й низькі звуки в інтервалах квінти, кварти, терції.

2. У сфері співу можливості дітей залежать від попередньої музичної підготовки: їх співацький діапазон може складатися від кількох звуків до октави і більше. Водночас у всіх дітей голосовий апарат ще не сформувався, дуже тендітний, змикання складок крайове. Це вимагає обережного й послідовного розвитку діапазону голосу, обмеження сили звучання.

3. У сфері сприймання музики можливості дітей досить широкі. Їм доступні такі основні жанри, як пісня, танець і марш, близька музика зображального характеру. Через незначний обсяг довільної уваги першокласників, твори повинні бути невеликими за обсягом, з яскравим музичним образом.

4. У сфері творчості можливості молодших школярів такі: вони легко відгукуються на різні творчі завдання, можуть імпровізувати на заданий образ, створювати ритмічні й мелодичні імпровізації на дитячих музичних інструментах, інсценізувати знайому пісню або інструментальну п'єсу зображального характеру.

Від якості музичних занять значною мірою залежить музичний розвиток молодших школярів у наступних класах. При цьому вчитель має прагнути не до вирівнювання учнів у їх музичному вихованні, оскільки це неодмінно приведе до гальмування розвитку частини дітей. Приділяючи особливу увагу тим дітям, які менш обдаровані музично, він повинен всіляко сприяти розвитку дітей обдарованих, ставити перед ними індивідуальні завдання. Вимогливість до учнів відповідно до їх здібностей є однією з умов підтримки одних, і попередженням від «зіркової хвороби» — інших, музично обдарованих дітей.

Слід враховувати, що молодший шкільний вік багатий на приховані можливості розвитку, які важливо своєчасно помітити і підтримати. Однакова недопустимо вважати першокласників менш розвиненими, ніж вони є насправді, як і перебільшувати їхні можливості. Вдумливе ставлення до вікових особливостей, фізичного і психічного розвитку дітей дасть учителеві можливість цілеспрямовано, без шкоди для вихованців здійснювати їхнє музичне навчання і виховання.

**Висновки.** Наші дослідження свідчать, що активна музична діяльність сприяє розвитку музичних здібностей молодших школярів: емоційна чутливість до музики, образність музичного сприймання й оригінальність музичного мислення, здатність до конструктивної, перетворювальної, імпровізаційної діяльності, виконавського артистизму тощо. Проте, виходячи з того, що навіть у межах одного класу діти часто виявляють дуже різний рівень розвитку музичних здібностей, побудова та подання відповідних завдань мають підпорядковуватися загальному правилу: вони мають визначатись відповідно до індивідуальних особливостей школяра. Актуальним для подальших наукових розвідок вважаємо розроблення інноваційних методик розвитку музичних здібностей учнів початкової школи у різних видах музичної діяльності — сприйманні, оцінюванні, творенні.

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**УДК 373.3.016:78**

**Руда Галина. Особливості музичної розвиненості учнів початкової школи.**

Досліджено сутність і структуру музичного розвитку учнів початкової школи. На основі аналізу психологічних і педагогічних праць зроблено висновки щодо особливостей музичної розвиненості в контексті загальної музичної освіти учнів початкової школи. Окреслено роль музичної діяльності у музичному розвитку учнів початкової школи. Розглянуто форми і методи музичного розвитку учнів початкової школи на сучасному уроці музичного мистецтва, зокрема засобами музичної діяльності. Наголошується на те, що уроки музичного мистецтва у повній мірі не задовольняють вимоги гуманістичної, розвивальної освіти. У шкільній практиці вони нерідко обмежуються набуттям знань, умінь і навичок, не використовуючи тих можливостей, які містить урок музичного мистецтва. Є об'єктивні потреби в більш глибокому теоретичному розумінні та практичному розкритті величезного й непересічного за значенням розвивального потенціалу загальної музичної освіти. Галузь музичної освіти постає осередком, що має надзвичайно широкі можливості для музичного розвитку дитини. Передумовами цього слугує розмаїття видів музичної діяльності й широке коло особистісних характеристик, що зазнають впливу під час музичних занять.

***Ключові слова:*** музичний розвиток, учні, початкова школа, музична діяльність, урок музичного мистецтва.

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# Ecological Tourism: Prospects of Development

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***Abstract***

Definitions of ecological tourism and concepts, adjacent to tourism, are considered. The value of ecotourism for the personality, societies, and the states is analyzed. Stages of formation and accumulation of knowledge of ecotourism and also the prospects of development of ecotourism, modern approaches to the description of science about tourism and places of tourism in the system of scientific knowledge are described.

**Keywords:** tourism, ecotourism, ecosystem, ecotrips, environment, tourist sphere, tourist industry.

It is known that our country has broad prospects for development of ecological tourism, expansion of the unique and steady network of ecotourist routes attractive to all categories of tourists, with further integration of the republic into the international market of similar services. Today Uzbekistan occupies one of leading places in Central Asia in the popular directions of ecotourism.

In the Republic of Uzbekistan consecutive measures for development of the tourist sphere having the wide potential for the solution in the short term of such major social and economic problems as creation of jobs, ensuring diversification of economy and the accelerated development of regions, inflow of currency receipts, increase in income and quality of life of the population of the country are carried out.

According to forecasts of experts of World Tourism Organization in the near future rates of his growth will be still high, and the brought income will make the significant contribution to development of economies of many countries of the world which are especially developing. It will allow stimulating social and economic growth in backward regions. Are laid great hopes on ecotourism in implementation of concepts of sustainable development of tourism and travel.

Ecological tourism wins the increasing popularity in the tourism industry. According to forecasts of the World Tourism Organization (WTO), he is among five main strategic directions of development of tourism till 2020 and according to estimates, the share of ecological tourism in the total amount of the world tourist industry, in recent years, has reached more than 10%, and rates of his growth by 2-3 times exceed the corresponding rates in all industry of tourism.

Development of ecotourism bears in itself complex support of system of environmental protection, preservation of a biodiversity and unique natural territories, maintenance of income of local population and is the perspective market for investment projects.

The concept "ecological tourism", perhaps, still strange sounds in our country though in Austria or Finland such type of rest is usual. "Ecosystem" in translation from Greek – "the house, the homeland". So, the science studying relationship of the person and the nature surrounding him of the house is also ecology. In the 1980th the academician D.S. Likhachev has expanded a concept of ecology, having included culture ecology here, having allocated a role of historical memory, spiritual continuity and having emphasized that isn't less important for preservation of human life (than a natural biological environment) the anvironment created by the culture of his ancestors and him. Thus, the ecotourism is not only a kind of the natural tourism uniting people who travel with the scientific and informative purposes and the sphere of interests which the surrounding natural and cultural environment, but also an opportunity to be an active defender of this environment are.

Also the term "ecological tourism" has been entered in the 80th of the 20th century by the ecologist Hector Ceballos Laskurain.

Today ecological tourism is a travel in untouched a civilization nature corners, the certain alternative type of rest and a recreation focused on new values, first of all on close communication with the nature.

For the English-speaking countries in it is greatest degrees the narrow concrete pragmatical interpretation of the term "ecotourism" has extended. Here ecological tourism is understood as a type of the trips made by small groups on the routes laid among the protected natural landscapes during which tourists get acquainted with unique objects, the phenomena and inhabitants of the nature for the purpose of ecological education and nature protection education.

In some countries of Europe and also in Russia, Uzbekistan big distribution was gained by broad interpretation of the term "ecotourism" that is in many respects connected with commercial interests.

So, ecological tourism is meant as private trips to a bosom of the wild nature. However at the corresponding extension of the term it is possible to carry to ecotrips, for example, scientific expeditions, summer ecological the camp – both school, and nurseries and a lot of things still. Even business trips – at observance of certain conditions – are included in the category of ecological. Conditions this following. One of the basic principles is as it was already told, the aspiration to minimize consequences for local ecological and sociocultural system. Besides, assistance to protection of this system in general and separate monuments and features becomes the purpose. The material interest of locals and economic efficiency of tourism is also important for stability of development of the region. Today by various estimates the ecotourism makes about 20% of all market of world tourism, and this figure grows. Together with consciousness of the population of the planet and understanding of that if we take care of it, and then it won't be made by anybody.

In Uzbekistan ecological tourism – one of the most perspective directions that is absolutely clear if to consider huge number of reserves in the country.

Ecological tourism – it isn't obligatory a travel on foot for physically hardy people with a heavy backpack behind shoulders. He can be and rather comfortable, but not at any cost, especially if it is about the untouched nature.

This definition has much in common with definition of the International organization of ecotourism (IOE): ecotourism – "a responsible travel to the natural zones, areas keeping the environment and the supporting welfare of locals".

The purposes of ecological tourism can be the most various. By this principle distinguish several types of ecological travel.

*1. Scientific tourism.*

In the course of scientific ecotours tourists participate in different researches of the nature, conduct field observations. For example, the ecotours connected with observation of behavior of birds in Latin America, calculation of number of populations of whales in the Pacific Ocean are widely known. As a rule, as tourist destinations in such tours the especially protected natural territories (EPNT) act: reserves, wildlife areas, national parks, nature sanctuaries. Foreign research expeditions and also field practicians of the students studying at natural-science faculties of the universities and institutes also belong to scientific tourism.

*2. Tours nature stories.*

It the travel connected with knowledge of the surrounding nature and local culture. As a rule, such tours represent set of the educational, popular scientific and thematic excursions lying on specially equipped ecological tracks. Most often they will also be organized across territories of reserves and national parks. Here campaigns of school students during which the teacher, by the guide leads tours and discussions about the nature belong. This type of ecotourism is especially popular in Germany therefore it is called still "the German model of development of ecotourism".

*3. Adventure tourism.*

This look integrates all travel connected with active ways of movement and outdoor recreation (outdoor), aiming at receiving new feelings, impressions, improvement by the tourist of physical shape and achievement of sports results. Here such types of tourism as mountaineering, rock-climbing, ice climbing, spelunking, mountain and pedestrian tourism, water, ski and alpine skiing tourism, a kanyoning, horse tourism, diving, paraplanerism, etc. belong. Many of these types of tourism appeared recently and are considered as extreme as are connected with big risk. At the same time it is the most high-growth, profitable, though expensive, a type of ecotourism. Adventure tourism is often called "heavy ecotourism" because thirst of tourists to adventures prevails over motives of conservation here.

Adventure tourism is often identified with sports tourism (mountaineering, speleology, paraplanerism, etc.) and active tourism when tourists move by means of so-called active ways (on foot, by bicycles, boats, rafts, etc.). Actually it isn't absolutely right.

Sports tourism as travel for the purpose of sports or visit of competitions includes also the types of tourism which aren't connected with an adventure, risk. For example, the soccer teams go to educational training camps or the fans fans following the team on an away match.

At the same time adventure tourism includes types of travel without active ways of movement. For example, jeeping – travel on the cross-country terrain on cross country vehicles, or BASE – jumps with a special parachute from aircraft, steep rocks, high anthropogenic objects (arc bridges, television towers, etc.) or deep-water immersions.

Now in the world market adventure tourism (adventure tourism) is not just travel with adventures, and tours with elements something unusual, exclusive for tourists. The same tour operator on this segment of the market can offer full range of services: from banal foot walk on the wood prior to an expedition to Antarctica.

For example, the leading English tour operator of "Exodus" offers the following types of adventure tours:

– Discovery and Adventure Holiday – travel to the remote regions of the planet with active movements.

– European Destinations – short-term inexpensive tours in OOPT of the European countries with movements by bicycles or on foot.

– Walking and Trekking – a basic type of adventure tourism. This pedestrian travel, a campaign without carrying of baggage (things of the tourist the special porter bears or they are transported transport) on special ecological tracks.

– Multi Activity Holydays – the travel which is assuming considerable physical activities lasting about one week, including rafting, a kanyoning, speleology, rock-climbing, fishing, jeeping.

– Overland – a travel on the trucks of the increased passability which are specially converted for housing. As a rule, tour will be organized to the countries with warm climate (Africa, South America, Southeast Asia), and tourists visit several countries for one trip.

*4. Travel to natural wildlife reserves, Especially Protected Natural Territories (EPNT)*

The high attractive of the unique and exotic natural objects and the phenomena which are on OOPT attract a great number of tourists. For example, 48% of the tourists arriving in Latin America aim at a travel to natural wildlife reserves. The management of many national parks, reserves turns ecological excursions into the real show.

In the activities for development, advance, tourism regulation, preparation of tourist shots the international organizations functioning in the sphere of tourism and travel actively react to changes and calls of an era of globalization. In new forms and models of interaction and cooperation, in measures for development and actions for advance of tourism current trends and perspective of development of future tourism are reflected.

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