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ҚАЗАҚ ҰЛТТЫҚ УНИВЕРСИТЕТІНІҢ

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ИЗВЕСТИЯ

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РЕСПУБЛИКИ КАЗАХСТАН

КАЗАХСКИЙ НАЦИОНАЛЬНЫЙ
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STATISTICAL ANALYSIS OF X-RAY SOLAR FLARE REGISTERED ON SEPTEMBER 10, 2017

Abstract. In this paper, we performed statistical studies of solar flares registered on September 10, 2017. We have identified several physical quantities of solar flares and estimated reconnection rate of solar flares. To determine the physical parameters we used images taken with the AIA instrument on board SDO satellite at wavelengths131 Å, 174 Å, 193 Å, 211 Å, 335 Å, 1600 Å, 1700 Å, 4500 Å, SXT - pictures, HMI Magnetogram, SOLIS Chromospheric Magnetogram, GOES XRT-data.

Keywords: solar flares, Alfven waves, reconnection rate.

Introduction

Solar flares are powerful bursts of radiation, while coronal mass ejections are massive clouds of solar material and magnetic fields that erupt from the Sun at high speeds. Harmful radiation from a flare cannot pass through Earth's atmosphere to physically affect humans on the ground, however - when intense enough - they can disturb the atmosphere in the layer where GPS and communications signals travel [1-13].

Solar flares can be classified according to their brightness in the x-ray wavelengths. There are three categories: X-class flares are big; they are major events that can trigger radio blackouts around the whole world and long-lasting radiation storms in the upper atmosphere. M-class flares are medium-sized; they generally cause brief radio blackouts that affect Earth's polar regions. Minor radiation storms sometimes follow an M-class flare. Compared to X- and M-class events, C-class flares are small with few noticeable consequences here on Earth. Solar flares are different to 'coronal mass ejections' (CMEs), which were once thought to be initiated by solar flares. CMEs are huge bubbles of gas threaded with magnetic field lines that are ejected from the Sun over the course of several hours. If a CME collides with the Earth, it can excite a geomagnetic storm [14-17].

Large geomagnetic storms have, among other things, caused electrical power outages and damaged communications satellites. The energetic particles driven along by CMEs can be damaging to both electronic equipment and astronauts or passengers in high-flying aircraft.

Solar flares, on the other hand, directly affect the ionosphere and radio communications at the Earth, and also release energetic particles into space. Therefore, to understand and predict 'space weather' and the effect of solar activity on the Earth, an understanding of both CMEs and flares is required.

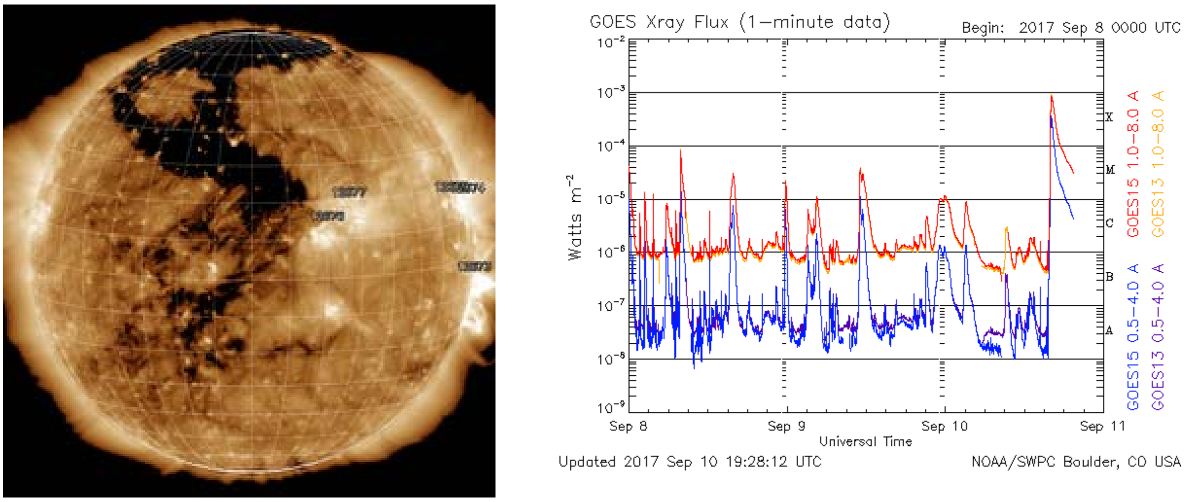

Figure 1 - Active area 12673 in AIA 193 Å and the total X-ray flux obtained in GOES 13 and GOES 15 [18]

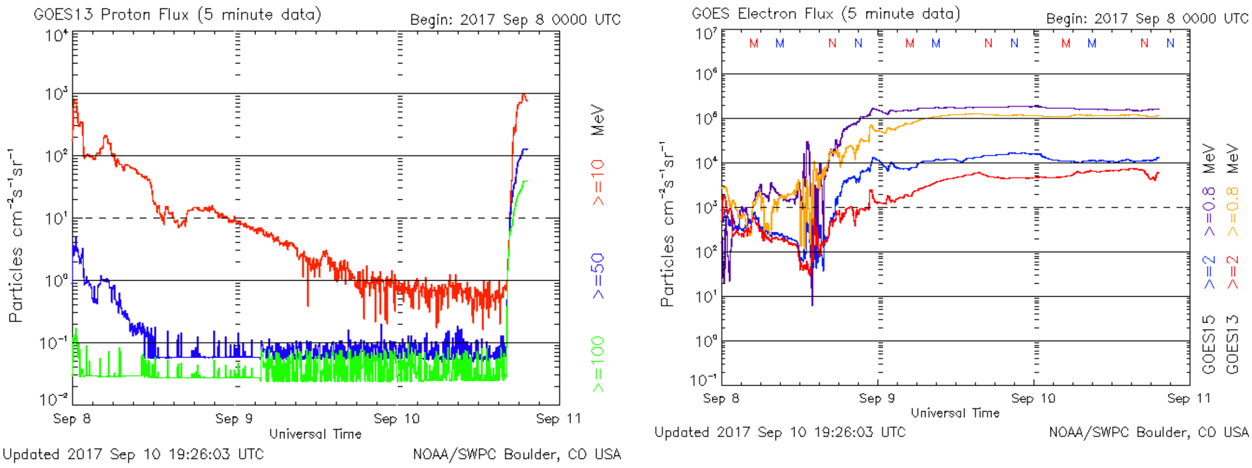

Figure 2 - Total proton and electron flux obtained in GOES 13 and GOES 15 [18]

DATA ANALYSIS

In the energy release process in solar flares, magnetic reconnection is generally considered to play a key role. The reconnection rate is an important quantity, because it puts critical restrictions on the reconnection model. To evaluate the reconnection rate in nondimensional form, $M_A \equiv \frac{V_{in}}{V_A}$, we must estimate the Alfven velocity in the inflow region: $V_A = \frac{B_{cor}}{(4\pi\rho)^{1/2}}$. Hence, if we measure the coronal density ρ , the spatial scale of the flare L, the magnetic flux density in the corona B_{cor}, and the timescale of flares τ_{flare}, we can calculate inflow velocity V_{in}, Alfven velocity V_A, and reconnection rate M_A [19].

Monitoring of solar flares in real time is performed by the Geostationary Operational Surveillance Satellite GOES. Electron, proton and X-ray fluxes are tracked by the satellites GOES 11, GOES 13 and GOES 15.

The sun emitted a significant solar flare, peaking at 12:06 p.m. EDT on Sept. 10, 2017. This flare is classified as an X8.2-class flare. X-class denotes the most intense flares, while the number provides more information about its strength. An X2 is twice as intense as an X1, an X3 is three times as intense, etc.

In Fig. 1 shown the images obtained on the board of GHN satellite in XRT. To determine the length of the loops, we used SXT images. From the SXT data, we get values for the length of the loops.

In Fig. 2 shows the total flux of X-rays and an electron, which was registered on September 10, 2017.

RESULTS

Using the method described in [20], we analyzed solar flare that have been registered on September 10, 2017. Examined the dependence of the reconnection rate from GOES class of solar flares. Figure 3 shows the dependence of the reconnection rate from GOES class.

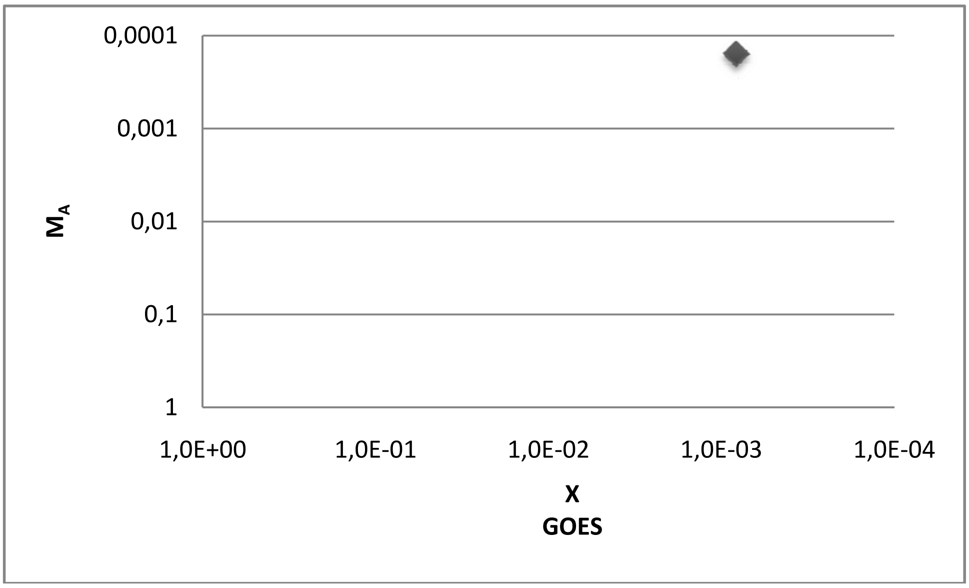

Figure 3 - Reconnection rate M_A plotted against the GOES class of the X flare

CONCLUSION

The values of reconnection rate are distributed in the range from $10^{-4} - 10^{-3}$. Here, the value of the reconnection rate decreases as the GOES class increases. The value of the reconnection rate obtained in this study is within 1 order of magnitude from the predicted maximum value of the Petschek model.

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2017 ЖЫЛҒЫ 10 ҚЫРКҮЙЕКТЕ ТІРКЕЛГЕН КҮН ЖАРҚЫЛЫН СТАТИСТИКАЛЫҚ ТАЛДАУ

Аннотация. Осы мақалада 2017 жылдың 10 қыркүйегінде тіркелген күн жарқылдарының статистикалық зерттеулері жүргізілді. Біз күн жарқылдарының физикалық мәндері мен қайта ұштасу жылдамдығын бағаладық. Физикалық параметрді анықтау үшін SDO спутникінің бортында AIA инструментінің 131 Å, 174 Å, 193 Å, 211 Å, 335 Å, 1600 Å, 1700 Å, 4500 Å толқын ұзындығында алынған және SXT суреті, HMI Magnetogram, SOLIS Chromospheric Magnetogram, GOES XRT- деректері пайдаланылды.

Түйін сөздер: күн жарқылы, альфвен жылдамдығы, қайта ұштасу жылдамдығы.

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СТАТИСТИЧЕСКИЙ АНАЛИЗ СОЛНЕЧНЫХ ВСПЫШЕК, ЗАРЕГИСТРИРОВАННЫХ 10 СЕНТЯБРЯ 2017 ГОДА

Аннотация. В этой статье нами проведены статистические исследования вспышек, зарегистрированных 10 сентября 2017 г. Мы определили несколько физических величин вспышек и оценили скорость пересоединения солнечных вспышек. Для определения физических параметров мы использовали снимки, полученные с инструмента AIA на борту спутника SDO на длинах волн $131\overset{o}{A}, 174\overset{o}{A}, 193\overset{o}{A}, 211\overset{o}{A}, 335\overset{o}{A}, 1600\overset{o}{A}, 1700\overset{o}{A}, 4500\overset{o}{A}$, SXT - снимки, HMI Magnetogram, SOLIS Chromospheric Magnetogram, GOES XRT-данные.

Ключевые слова: солнечные вспышки, альфвеновская скорость, скорость пересоединения.

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SOLAR ACTIVITY MONITORING FOR THE PERIOD APRIL 10-20, 2017

Abstract. In this paper was monitored solar flares registered in the period 10-20 April 2017. Was given brief analysis of solar flares registered in these days, also has shown the duration of time and peak of solar flares in Universal time.

Keywords: solar flare, X-rays.

Monitoring of solar flares in a real time is carried out by the Geostationary Operational Environmental Satellite or GOES [1]. Data on the electrons, protons, and X-rays were taken from satellites GOES 13, GOES 14 and GOES 15 [2-15].

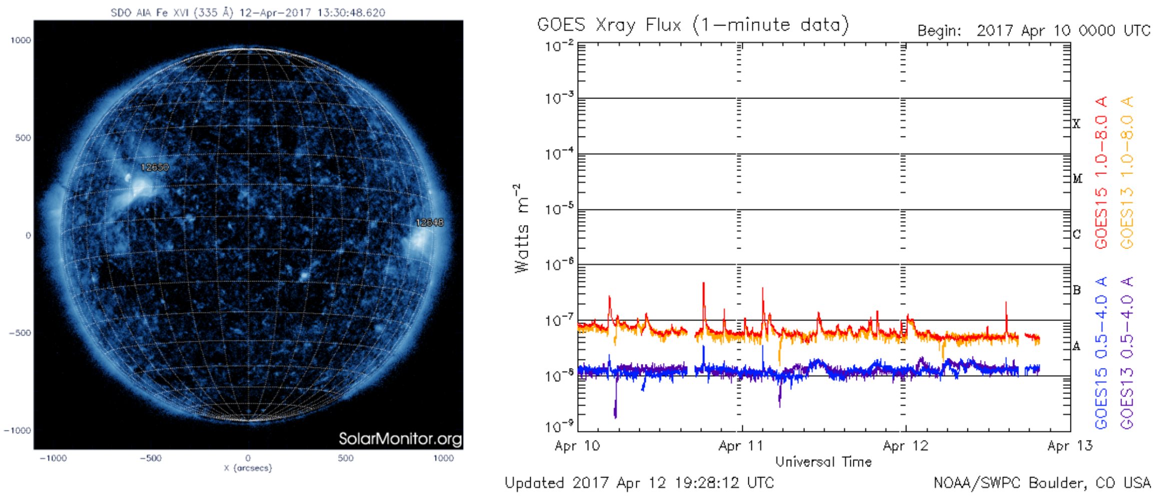

Figure 1 - Active area 12650 (XRT Hinode) and the total X-ray flux obtained in GOES 13 and GOES 15 [1]

On April 10, 2017, on the Sun, 5 class M flares were registered. In total, 5 classes are distinguished in the scale of solar flares: A, B, C, M and X, each subsequent of which exceeds the previous power by 10-100 times. The event, more accurately estimated as B2.6, occurred in the morning and observed for about 13 minutes with a maximum at 04:36 UT [16-18].

On April 11, at 02:56 UT recorded the first flare of class B3.9 with a duration of 4 minutes from the highs of 03:00 UT on the Sun. In total, 5 solar flares of class B were registered.

On 12 April midnight, there was an eruption of class B1.3 at 00:07 UT and was observed for about 4 minutes with a maximum of 00:11 UT. In total, 2 flares of class B were registered.

On April 14 around 16:18 on World time there was a fairly strong release of solar matter into space. The solar flare is estimated as B1.1 and its maximum was observed at 16:21 on world time. In total, 1 solar flare of class B were registered.

On April 16, 2017, around 21:53 GMT, another solar flare of class B2.6 was registered and was observed for about 5 minutes with a maximum at 21:58 UT. In total, 2 flares of class B were registered.

On April 17, at 01:28, the first M class flare B3.6 was registered. The event occurred in the active area of 12650 and was observed for about 11 minutes with a maximum at 01:39 UT. In total, 8 flares of class M and one flare of class C were registered.

On April 18, in the active area 12650 at 00:24 GMT, a solar flare class B2.3 with a duration of 4 minutes occurred. In total, 5 flares of class B and one 2 flares of class C were registered.

On April 19 at 10:01 UT, another eruption of solar flare class B5.3 was registered. The event occurred in the active area of 12651 and was observed for about 4 minutes with a maximum at 10:05 UT. In total, 4 solar flares class of B were registered.

On April 20, 4 class B solar flares were registered. In active area 12651 at 06:49 GMT, solar flare class of B8.0 occurred and was observed for about 7 minutes with a maximum at 06:56 UT.

Table 1 - Solar flares registered in the period from 10 to 20 April 2017 [1, 2]

Date	X-ray class	Integrated flux (J/m^2)	Start time (hhmm)	End time (hhmm)	Maximim time (hhmm)
10/04/17	B 26	2.7E-04	0423	0447	0436
	B 11	5.5E-05	0836	0847	0839
	B 13	1.2E-04	0953	1012	0958
	B 47	2.1E-04	1816	1828	1823
	B 16	5.8E-05	2117	2126	2122
11/04/17	B 39	1.1E-04	0256	0304	0300
	B 13	1.8E-04	0345	0412	0400
	B 13	1.1E-04	1059	1116	1111
	B 10	3.4E-05	1846	1854	1850
	B 14	9.8E-05	1938	1953	1945
12/04/17	B 13	1.5E-04	0007	0032	0011
	B 21	8.8E-05	1427	1438	1432
14/04/17	B 11	3.1E-05	1618	1625	1621
16/04/17	B 26	2.2E-04	2153	2210	2158
	B 40	1.2E-03	2238	2339	2305
17/04/17	B 36	3.1E-04	0128	0146	0139
	C 20	4.4E-03	0217	0310	0247
	B 40	1.3E-04	0554	0602	0558
	B 71	4.2E-04	0713	0727	0721
	B 36	1.4E-04	1440	1450	1446
	B 32	1.2E-04	1624	1633	1630
	B 57	4.5E-04	1846	1906	1853
	B 75	1.0E-03	2121	2153	2142
	B 20	7.7E-05	2339	2348	2344
18/04/17	B 23	8.1E-05	0024	0032	0028
	B 17	5.8E-05	0218	0226	0222
	B 56	2.3E-04	0531	0542	0537
	B 21	8.3E-05	0551	0600	0554
	B 69	3.6E-04	0631	0646	0640
	C 33	3.1E-03	0929	0955	0941
	C 55	1.6E-02	1921	2049	2010
19/04/17	B 53	1.1E-04	1001	1007	1005
	B 25	5.6E-05	1231	1237	1234
	B 72	1.7E-04	1632	1639	1636
	B 16	4.4E-05	1753	1800	1756
20/04/17	B 80	4.4E-04	0649	0704	0656
	B 19	9.2E-05	0842	0853	0846
	B 26	1.8E-04	1043	1058	1049
	B 37	1.6E-04	2117	2127	2123

During the period from 10 to 20 April, 36 M class flares and 3 C class flares were registered [19-20]. The solar flares are recorded by a network of space observatories: telescopes on the board of American SDO observatory, LASCO coronagraphs (European SOHO station), and also by both STEREO satellites (USA), which are now at a giant distance of hundreds of millions of kilometers from our planet.

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2017 ЖЫЛДЫҢ 10-20 СӘУІР АРАЛЫҒЫНДАҒЫ КҮН ЖАРҚЫЛЫНЫҢ БАҚЫЛАУЫ

Аннотация. Осы мақалада 2017 жылдың 10-20 сәуірінде тіркелген күн жарқылдарының бақылауы жүргізілді. Осы кундері тіркелген күн жарқылдарының кысқаша талдамасы жүргізілді, сонымен қатар күн жарқылының уақыт ұзақтылығы және максимумы Бүкіл әлемдік уақытта көрсетілген.

Түйін сөздер: күн жарқылы, рентген сәулесі.

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МОНИТОРИНГ СОЛНЕЧНЫХ ВСПЫШЕК В ПЕРИОД 10-20 АПРЕЛЯ 2017 ГОДА

Аннотация. В этой статье был проведен мониторинг солнечных вспышек зарегистрированных в период 10-20 апреля 2017 года. Был проведен краткий анализ солнечных вспышек зарегистрированные в эти дни, а также показана продолжительность времени вспышки и ее максимум по Всемирному времени.

Ключевые слова: солнечная вспышка, рентгеновское излучение.

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THE STUDY OF THE NEUTRON HALO OF THE ^{11}BE NUCLEUS TAKING INTO ACCOUNT THE INFLUENCE OF AN EXTERNAL FIELD

Abstract. The aim of work is a theoretical study of the Coulomb breakup of halo nuclei in time-dependent quantum-mechanical approach. Exotic nuclei are the subject of intensive experimental research.Theoretical studies of Coulomb breakup of halo nuclei are relevant for the interpretation and planning of experiments for the study of light nuclei on radioactive beams.The investigations with beams of radioactive nuclei have opened new prospects in studying the structure of the atomic nucleus and have found wide applications in other areas of physics, including nuclear astrophysics. The halo is one of the most intensively studied objects in modern low-nucleus physics. A characteristic feature of halo nuclei physics is correlations between the mechanism of nuclear reaction and structure.

The breakup is one of the important tools for thetheoretical study of the properties of halo nuclei. In these reactions, the information from the breakup of the projectile into fragments can be used to make a conclusion about the properties of the halo part of the wave function. With good approximation, the breakup could be considered as atransition from bound state of two (three) particles to the continuum, due to changing Coulomb field.

In this paper, the energy levels of the halo nucleus of^{11}Be are calculated, taking into account the effect of an external magnetic field. The ^{11}Be nucleus is regarded as a neutron halo consisting of ^{10}Be core and one neutron. This work is the initial stage of the work on the investigation of the breakup of halo nuclei in the quantum-mechanical approach.

Key words: Halo nucleus, Coulomb breakup, breakup cross section, exotic states of the nuclei, nonstationary Schrödinger equation, energy spectrum, nuclearpotential.

Introduction. For the first time, nuclei with a neutron halo were discovered in 1985 by Tanikhata and et al. [1,2], where such exotic systems were tightly bound core and surrounded by a diffuse nuclear cloud. These systems were observed in the ground states (g.s.) of some light, neutron-rich radioactive nuclei located near the neutron stability boundary [3]. Previously it was believed that a halo could be formed only in radioactive nuclei located close to the neutron drip line. However, in the late 50's of last century, long before the discovery of the halo, A.I. Baz actually predicted [4] the possibility of its appearance even in stable nuclei near the neutron or proton emission thresholds. In particular, it was shown in [5] that the excited state of 3.09 ($1/2^-$) MeV of the stable ^{13}C nucleus could have a halo structure with an increased radius.

Coulomb breakup is one of the main tools for studying the halo nucleus. The crosssection contains useful information about the structure of the halo. Thus, this topic is the subject of intense experimental and theoretical research. Among the halo nuclei, the ^{11}Be nucleus is of particular importance, since the relative simplicity of its structure allowsmore accurate theoretical studies. In fact, the bound states of the ^{11}Be nucleus can be described quite well as a ^{10}Be nucleus and a weakly bound neutron. With a good approximation, the decay can be regarded as a transition from a two-particle bound state to a continuum due to a changing Coulomb field in the process of collision of nuclei with a target [6].

The neutron halo effect is caused by the presence of weakly bound states of neutrons located near the continuum. The small value of the binding energy of a neutron (or a group of neutrons) and the short-range nature of nuclear forces lead to the tunneling of neutrons into the outer peripheral region over large distances from the core of the nucleus. In this case, the distribution density of peripheral neutrons is much smaller than the neutron distribution density inside the core [7].

Among the neutron halo nuclei, the nucleus ^{11}Be is of particular interest. In the simplest approximation, it can be considered as a two-particle system consisting of a ^{10}Be core and a weakly bound neutron. The halo-nucleus is described quite well by the wave function, which is the product of the wave functions of the core and the external halo. A number of experimental facts confirm that nucleons forming a nuclear halo have little effect on the core of the nucleus [6]. The most famous nuclei having the structure of a single-neutron halo are ^{11}Be, ^{11}Li, ^{17}C, ^{19}C and etc. [8]. They also have small binding energies, anomalously large sizes, narrow momentum distributions of fragments after the breakup, large interaction cross sections and electromagnetic dissociation.

The practical way of studying the halo structure is to investigate collisions of two nuclei with the transfer of energy and momentum. As a result, the transient properties of nuclear systems are studied in nuclear reactions, namely, the transition from the ground state to excited states [8]. The breakup is one of the important tools for thetheoretical study of the properties of halo nuclei. In these reactions, the information from the breakup of the projectile into fragments can be used to make a conclusion about the properties of the halo part of the wave function. The Coulomb breakup is of particular interest,because the uncertainty about the assumption that the nuclear interaction between the projectile and the target plays an important role. Nevertheless, in order to correctly extract information from the cross sections, the accuracy of the description of the reaction mechanism must be established [9].

A characteristic feature of the physics of the halo nuclei is the close relationship between the mechanism of the nuclear reaction and the structure of the nucleus. The primary analysis [1,2] of experimental data on the cross sections of the interaction of nuclei with a halo has already led to the determination of the large material radii of these systems. Since in the known nuclei with a two-neutron halo the ground state is the only bound state, the breakup of nuclei with ahalo in binary collisions is the final process of any reaction accompanied by excitation of the exotic system. The development of adequate models of the breakup is of great practical value as a means of extracting reliable information on the structure of nuclei with halo and the dynamics of the interaction processes [10].

In this paper,theinfluence of an external magnetic field on the ground state of the ^{11}Be nucleus is investigated, the splitting of the energy levels are calculated by numerical and analytical methods. The first order of perturbation theory was taken as an analytical method [11].

1. Numerical methods for solving the stationary Schrödingerequation. The problem is reduced to solving the stationary Schrödinger equation (SE):

$$H\psi_{Nlm} = E_N\psi_{Nlm} \tag{1}$$

The wave function could be written in the form:

$$\psi_{Nlm}(r) = R_{Nl}(r)Y_{lm}(\theta,\varphi) \tag{2}$$

where$Y_{lm}(\theta,\varphi)$-is a spherical function.

The Hamiltonian of the interaction [8]:

$$H_0(r) = -\frac{\hbar^2}{2\mu}\Delta + V_{cf}(r) \tag{3}$$

Then for the radial part $R_{Nl}(r)$of the wave function we obtain the equation:

$$\left[-\frac{\hbar^2}{2\mu}\Delta + \frac{\hbar^2 l(l+1)}{2\mu\, r^2} + V_{cf}(r)\right]R_{Nl}(r) = E\, R_{Nl}(r) \tag{4}$$

where $\mu = \frac{m_n \cdot m_c}{M}$ reduced mass, m_n, m_c и $M= m_n +m_c$ –respectively, the masses of the neutron, core, and nucleus of ^{11}Be.

To solve theproblem (4) it is more convenient to use the system of units, where - energy, potential and mass are measured in the same energy units - MeV, and the radius of nucleus in fm, and ħc = 197.328 MeV · fm. Then equation (4) can be written in the form:

$$\left[-\frac{41{,}443}{2\left(\frac{\mu}{m_n}\right)}\frac{d^2}{dr^2} + \frac{41{,}443\ l(l+1)}{2\left(\frac{\mu}{m_n}\right) r^2} + V_{cf}(r)\right] R_l(r) = E\ R_l(r) \tag{5}$$

The potential $V_{cf}(r)$ consists of a central term and a spin-orbit interaction term taking into account the spin of the neutron **I** and the angular momentum **L** of the relative motion of the neutron-core [6,9].

$$V_{cf}(r) = V_0(r) + \mathbf{LI} V_{LI}(r) \tag{6}$$

$V_{cf}(r)$ is an internal interaction between the nucleus and the fragment of the projectile [9]. The central potential of equation (6):

$$V_0(r) = -V_l\, f(r, R_0, a) \tag{7}$$

where the Woods-Saxon form factor:

$$f(r, R_0, a) = \left[1 + \exp\left(\frac{r-R_0}{a}\right)\right]^{-1} \tag{8}$$

Spin-orbit interaction is expressed as [9]:

$$V_{LI}(r) = V_{LS}\frac{1}{r}\frac{d}{dr}\, f(r, R_0, a) \tag{9}$$

The values of the potential parameters are given in Table 1, they are chosen as in [6].

Table 1 - Potential parameters

$V_{l=0}$ (MeV)	$V_{l>0}$ (MeV)	V_{LS} (MeV fm^2)	a (fm)	R_0 (fm)
59.5	40.5	32.8	0.6	2.669

Here V_l is the depth of the Woods-Saxon potential, a is the diffuseness, and R_0 is the radius of the ^{11}Be ($R_0 = 1.2A^{1/3}$fm). The standard value V_{LS} is used for the potential depth *ls* for the p-shell core [1].

We seek the solution of the SE (5) under boundary conditions using numerical methods of the inverse iteration [12], finite-difference [13] and the sweep methods [12].

$$\begin{Bmatrix} R_{Nl}(r) \to const, r \to 0 \\ R_{Nl}(r) \to 0, r \to \infty \end{Bmatrix} \tag{5}$$

The method of reverse iteration is characterized by sufficiently rapid convergence to the solution. The accuracy of the result must be checked on the residual. The accuracy of the computational scheme is equal to $\Delta_i = \left|E^{(i)} - E^{(i-1)}\right| < 10^{-6}$. In the equation, the second-order derivative can be simplified for a computer scheme using finite-difference approximation, described in detail in paper [7]. A radial grid is introduced over r_j on the interval r ∈ $[0, r_m]$, for convenience we have introduced the notation$R(r_j)=R_j$. The wave function for the first iteration will be foundby sweep method, then the normalization will be checked. Thus, the energy level will be found. Negative energy states are normalized and describe either the physical bound states of the nucleus ^{11}Be or states forbidden by the Pauli principle[9].

1.1 Numerical methods for solving the stationary Schrödinger equation.

1.1.1The results: energy spectrum of[11]Be.The stationary Schrödinger equation (radial part) is solved by the method of reverse iteration [12]. The solution scheme is as follows:

$$\begin{cases} \hat{A}\vec{R} = E\vec{R} \\ (\widehat{A} - \hat{I}E^{(0)})\,\vec{R}^{(i)} = \vec{R}^{(i-1)} \\ E^{(i)} = E^{(0)} + \frac{\mathbf{1}}{\widehat{\mathbf{R}}^{(i)},\widehat{\mathrm{R}}^{(\mathbf{i-1})}} \end{cases}, i = \overline{1, \iota_{max}} \tag{11}$$

where$E^{(0)}$ is the initial approximation for the energy, i - is the iteration number, $\hat{R}^{(0)}$- is the initial vector, and the calculated finite vector $\hat{R}^{(i)}$ - is normalized at each iteration $\hat{R}(r) = \widehat{\varphi}^{(\iota_{max})}$.

The advantage of this method is that the final answer will not depend on the choice of the initial approximation, since the answer quickly converges. Nevertheless, the accuracy of the result must be checked on the residual.

From equation (11) that the accuracy of the computational scheme is

$$\Delta_i = \left|E^{(i)} - E^{(i-1)}\right| < 10^{-6} \tag{12}$$

orthe discrepancy is$\delta_i < 10^{-6}$:

$$(\widehat{A} - \hat{I}E^{(i)})\,R^{(i)} = \delta_i \tag{13}$$

1.1.2 The sweep method.We seek the solution SE (5) in the form (11) under the boundary conditions:

$$\begin{Bmatrix} R_{Nl}(r) \to const, r \to 0 \\ R_{Nl}(r) \to 0, r \to \infty \end{Bmatrix} \tag{14}$$

In the equation there is a second-order differential, which can be simplified for a computational circuit using the finite-difference method, described in detail in [13]:

$$\frac{d^2}{dr^2}\left(R_j^{(1)}\right) = \frac{R_{j+1}^{(1)} - 2R_j^{(1)} + R_{j-1}^{(1)}}{h^2} \tag{15}$$

Here we introduce a radial mesh with respect to r_j, where h is the step along the grid r_j, for convenience, we have introduced the notation R (r_j) = R_j.

The Schrodinger equation goes to the following form

$$\hat{c}_j\vec{R}_{j+1}^{(1)} + \hat{d}_j\vec{R}_j^{(1)} + \hat{e}_j\vec{R}_{j-1}^{(1)} = \vec{R}_j^{(0)} \tag{16}$$

It can be seen that equation (16) consists of a three-diagonal matrix. The solution will be solved in the following form, using the sweep method [12]:

$$\begin{gathered} \overline{\Psi}_j = \alpha_j\overline{\Psi}_{j+1} + \beta_j \\ \overline{\Psi}_{j-1} = \alpha_{j-1}\overline{\Psi}_j + \beta_{j-1} \end{gathered} \tag{17}$$

Substituting $\bar{R}_{j-1} = \alpha_{j-1}\overline{R}_j + \beta_{j-1}$into equation (16), we find that

$$\bar{R}_j = \alpha_j{'}\overline{R}_{j+1} + \beta_j{'}$$

where the coefficients are:

$$\alpha_j{'} = -\left(\hat{d}_j + \alpha_{j-1}\hat{e}_j\right)^{-1} \cdot \hat{c}_j$$

$$\beta_j' = \left(\hat{d}_j + \alpha_{j-1}\hat{e}_j\right)^{-1}\left(\vec{R}_j^{(0)} - \beta_{j-1}\cdot\hat{e}_j\right) \tag{18}$$

Using this scheme, at first the coefficients α_j' and β_j' are found (direct sweep), then the radial wave function $\vec{R}_j^{(1)}$ is found by reverse sweep. Further, the normalization is checked. Thus, there is a wave function for the first iteration. Further, as described above, the energy level is found. Negative energy states are normalized and describe either the physical bound states of the projectile or states forbidden by the Pauli principle [9].

1.2 Results:the energy spectrum of ^{11}Be. Applying these numerical methods, in this paper, the energy levels of the ^{11}Be nucleus for the Woods-Saxon potential were reproduced as a test program as in [6,9]. The ^{11}Be nucleus is regarded as a neutron halo consisting of a ^{10}Be core and one neutron [6,9]. As a result, energy levels were obtained for the ground and first excited states. These data are given in Table 2 and compared with the results of [9].

Table 2 - The energies of the ground and excited statesof ^{11}Be

J^{π}	l	$E_{exp.}$(MeV) [14]	$E_{theor.}$(MeV) [9]	$E_{theor.}$(MeV) (this work)
$\frac{1}{2}^{+}$	0	-0.503	-0.5013	-0.5013
$\frac{1}{2}^{-}$	1	-0.183	-0.1844	-0.1844

As already stated above, for a finite-difference approximation of a second-order equation with respect to a radial variable r, a grid was used on the interval $r \in [0, r_m]$, where r_m = 800 fm for the ground and first excited states [9]. The convergence of the computational scheme for $\Delta r \to 0$ is presented in Table 3, where N_r is the number of points, Δr is the step along the radial grid, and E is the energy of the bound state.

Table 3- Convergence of a computational scheme on a homogeneous radial mesh

N_r	Δr	E, l=0	N_r	Δr	E, l=1
2000	0.4	-0.501318	2000	0.4	-0.184423
4000	0.2	-0.780709	4000	0.2	-0.1883722
8000	0.1	-0.845679	8000	0.1	-0.1903396
16000	0.05	-0.861629	16000	0.05	-0.1913216

2 The splitting of the energy levels of ^{11}Be due to the influence of an external magnetic field (Zeeman splitting). In this chapter, the effect of an external magnetic field on the halo state of the ^{11}Be nucleus is studied, i.e. the splitting of the energy levels by a numerical method is calculated and numerical results are compared with the analytical solution. The first order of perturbation theory was chosen as an analytical method [11].

Under the influence of an external magnetic field, the magnetic moments of the nuclei are oriented in a certain way and it becomes possible to observe transitions between the nuclear energy levels associated with these different orientations: transitions occurring under the action of radiation of a certain frequency. The quantization of the energy levels of the nucleus is a direct consequence of the quantum nature of the angular momentum of nucleus, assuming 2I + 1 values. The spin quantum number (spin) I can take any value that is a multiple of ½. The splitting of energy levels in a magnetic field can be called a nuclear Zeeman splitting, since it is analogous to the splitting of electron levels in a magnetic field (the Zeeman effect) [11].

Nuclear magnetic resonance (NMR) based on the Zeeman effect is widely used in nuclear spectroscopy. At present, it is difficult to indicate a field in the natural sciences, where NMR has not been used to some extent. NMR spectroscopy methods are widely used in chemistry, molecular physics, biology, agronomy, medicine and in the study of natural formations, etc. Devices for the investigation of the entire human body by methods of magnetic resonance (by NMR tomography methods) have been developed and are being manufactured [16].

Let's write the radial Schrödinger equation (5) adding an external field ΔV_{μ}:

$$\left[\frac{\hbar^2}{2m}\frac{d^2}{dr^2}+\frac{\hbar^2}{}\frac{l(l+1)}{2mr^2}+V(r)+\Delta V_{\mu}\right]R_l(r)=ER_l(r) \tag{19}$$

We rewrite the equation, corrected for our system of units:

$$\left[\frac{\hbar^2}{2m{r_0}^2E_0}\frac{d^2}{dr^{'2}}+\frac{\hbar^2\,l(l+1)}{2\mu {r_0}^{'2}E_0}-\frac{V_0^{'}}{1+\exp\left(\frac{r'-R}{a}\right)}+\frac{\Delta V_{\mu}}{E_0 r_0}\right]R_l\left(\frac{r}{r_0}\right)=\frac{E}{E_0}R_l\left(\frac{r}{r_0}\right) \tag{20}$$

$$\left[-\frac{k_1}{2}\frac{d^2}{dr^2}+\frac{k_1\,l(l+1)}{2r^2}+V(r)+\Delta V_{\mu}\right]R_l(r)=E_lR_l(r)\,, \tag{21}$$

where the additional potential ΔV_{μ} describes the interaction of the neutron spin with an external magnetic field, since, as mentioned above, the neutron halo nucleus ^{11}Be is considered as system of ^{10}Be+nand is defined as $\Delta V=B\cdot\mu_n\cdot\hat{S}_n$;correction factors for the nuclear system of unitsk_1 =41,443 and $k_2=3.15\cdot10^{-13}\frac{MeV}{Gfm}$,here B- is the strength of the magnetic field, μ_n- is the magnetic moment of the neutron, $\hat{S}_n$- s the projection of the spin on the axis. Since the neutron spin is s=1/2, the projection of the spin on the selected direction takes two values: +1/2 and– 1/2. In the (21), the wave function$R_l(r)$must be replaced by the spin wave function $R_l(r)\to R_l(r)\cdot\chi_m$, where χ_m are two-component spinors, and the spin operators are 2 × 2 matrices. For the case when the field is directed along the z axis: $\hat{s_z}=\pm\frac{1}{2}\begin{pmatrix}1 & 0\\ 0 & -1\end{pmatrix}$.

In the representation $|s\,m_s\rangle$, where the projection of the spin to the axis takes the values $m_s=+\frac{1}{2}$,$m_s=-\frac{1}{2}$ then the basis vectors of this representation have the form [14]

$$\chi_{\frac{1}{2}\frac{1}{2}}=\begin{pmatrix}1\\0\end{pmatrix},\ \chi_{\frac{1}{2},-\frac{1}{2}}=\begin{pmatrix}0\\1\end{pmatrix}$$

Introducing the spin wave function, it can be seen that the SE is splitted into two equations

$$E'_{lm=\frac{1}{2}}=E_l+\Delta E_{m=\frac{1}{2}}$$

$$E'_{lm=-\frac{1}{2}}=E_l+\Delta E_{m=-\frac{1}{2}} \tag{22}$$

so the level shifts are defined as:

$$\Delta E_{m=\frac{1}{2}}=<R_{lm}^{(r)}|\frac{1}{2}k_2\cdot B\cdot\mu_n|R_{lm}^{(r)}>$$

$$\Delta E_{m=-\frac{1}{2}}=<R_{lm}^{(r)}|-\frac{1}{2}k_2\cdot B\cdot\mu_n|R_{lm}^{(r)}> \tag{23}$$

The same can easily be calculated to the case when the field is directed along the x or y axes.

Next, the program was modified to calculate the energy shifts by introducing the spinor, so the number ofmatrices and vectors are doubled.

Stationary Schrödinger Equation

$$H_0 R_l(r) = E R_l(r) \quad (24)$$

can be rewritten in the following form:

$$\sum_{j=1}^{M} H_{ij}^{(0)} R_j = \sum_j \delta_{ij} E\, R_j = E R_i \quad (25)$$

In order to describe the nuclear interaction, we used the Woods-Saxon potential with the parameters given in the first chapter and the potential of the Gauss shape to verify the technique [14]:

$$V(r) = V_0 e^{-\left(\frac{r}{r_0}\right)^2} = V_0 e^{-gr^2} \quad (26)$$

For $l = 0$, the potential depth is chosen as for the Woods-Saxon potential $V_0 = -59.5$ MeV, the potential width$g = \frac{1}{r_0^2} = 0.117\ fm^{-2}$.

Figure 1 shows the potentials of Woods-Saxon(WS) and Gauss (Gof the ground state as a function of the radial coordinate. According to the graph, it can be used the interval from 0 to r_m=8fm.

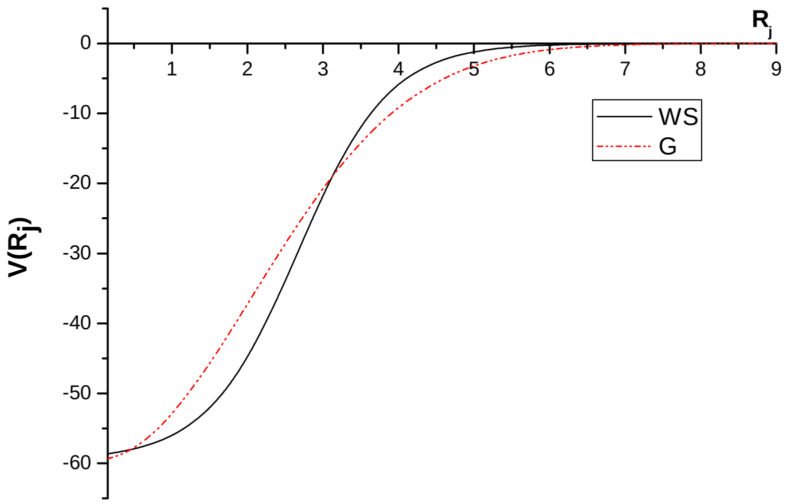


Figure 1 - The shape of the Woods-Saxon and Gauss potential for the ground state of ^{11}Be as a function of the radial variable

The results for the ground state are shown in Table 4. The numerical results are compared with the analytical solution, and the first order of perturbation theory is chosen as the analytical one [12].The SE, taking into account the perturbation, is written as:

$$(H_0 + \Delta V) R_0(r) = E_0' R_0(r) \quad (27)$$

$$E_0' = E_0 + \Delta E$$

The energy shifts in perturbation theory are calculated as:

$$\Delta E_{\frac{1}{2}} = \int_0^\infty R_0(r) \Delta V_{\frac{1}{2}}(r)\, R_0(r) dr$$

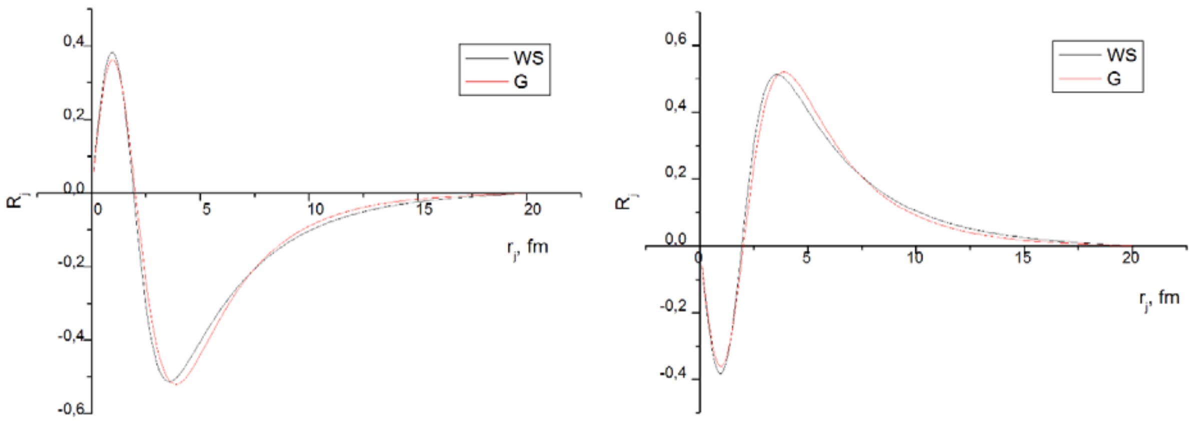
$$\Delta E_{-\frac{1}{2}} = \int_0^\infty R_0(r) \Delta V_{-\frac{1}{2}}(r)\, R_0(r) dr \quad (28)$$

The field strength varied from 0.1 to 2000 Gauss; it can be seen that the results are in good agreement with the analytical ones.

Table 4 - The energy shift of the ground state of ^{11}Be due to the influence of an external magnetic field

R_m=8 M=200	$\Delta E_{pert}(B_z)$ perturbation	$\Delta E_{num}(B_Z)$ Gauss num.	$\Delta E_{num}(B_Z)$ WS num.	$\Delta E_{pert}(B_z)$ perturbation	$\Delta E_{num}(B_z)$ Gaussnum.	$\Delta E_{num}(B_Z)$ WSnum.
B (Gauss)	m_s=+1/2 spin projection			m_s= - 1/2 spin projection		
0.1	0.0003	0.0003	0.0003	-0.0003	-0.0003	-0.0003
1	0.0030	0.0030	0.0030	-0.0030	-0.0030	-0.0030
10	0.0300	0.0301	0.0301	-0.0300	-0.0300	-0.0300
100	0.3008	0.3008	0.3008	-0.3008	-0.3008	-0.3008
200	0.6016	0.6016	0.6016	-0.6016	-0.6016	-0.6016
300	0.9024	0.9025	0.9025	-0.9024	-0.9025	-0.9025
400	1.2033	1.2033	1.2033	-1.2033	-1.2033	-1.2033
500	1.5041	1.5041	1.5041	-1.5041	-1.5041	-1.5041
1000	3.0082	3.0082	3.0082	-3.0082	-3.0082	-3.0082
2000	6.0165	6.0165	6.0165	-6.0165	-6.0165	-6.0165

Figure 2 shows the wave functions of the s-state of ^{11}Be for the spin projection of +1/2 (Fig. a) and -1/2 (Fig. b). Black is denoted for the Woods-Saxon (WS) potential, redline is Gauss (G). When the magnetic field is varied, the wave functions do not change.



a) b)

Figure 2 - a) Radial wave function when the spin is directed upwards (+1/2) and b) when the spin is directed downward (-1/2)

Conclusion. Using numerical methods, in this paper, the energy levels of the ^{11}Be nucleus were reproduced as a test program using the Woods-Saxon potential for describing the nuclear interaction as in [6,9]. The ^{11}Be nucleus is regarded as a neutron halo consisting of a ^{10}Be core and one neutron [6,9].

Also, the energy level shifts were calculated due to the influence of the magnetic field, using two different potentials: the Woods-Saxon and Gauss forms. The numerical results coincide with the analytical solution, and the first order of perturbation theory is chosen as the analytical one.

This work is the initial stage of work on the investigation of the breakup of halo nuclei in the quantum-mechanical approach. A detailed investigation is planned to research the effect of the external field on the breakup of the halo nucleus, using the numerical method for solving the nonstationary SE.

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ИЗУЧЕНИЕ НЕЙТРОННОГО ГАЛО ЯДРА ^{11}BE С УЧЕТОМ ВЛИЯНИЯ ВНЕШНЕГО ПОЛЯ

Аннотация. Цельюработыявляетсятеоретическое исследование процессов кулоновского развала гало ядер в рамках нестационарного квантово- механического подхода. Экзотические ядра являются предметом интенсивного экспериментального исследования. Теоретические исследования кулоновского развала гало ядер актуальны для интерпретации и планирования экспериментов по изучению легких ядер на радиоактивных пучках. Исследования с пучками радиоактивных ядер открыли новые перспективы в изучении структуры атомного ядра и нашли широкие приложения в других областях физики, включая ядерную астрофизику. Гало ядра являются одним из наиболее интенсивно исследуемых объектов в современной малонуклонной ядерной физике. Характерной особенностью физики ядер с гало является тесная взаимосвязь механизма ядерной реакции и структуры.

Развал является одним из важных инструментов для изучения свойств гало ядер. В этих реакциях, информация, поступающая от диссоциации снаряда на фрагменты может быть использована, чтобы сделать вывод о свойствах гало части волновой функции. С хорошим приближением, развал гало ядра можно рассматривать как переход от связанного состояния двух (трех) частиц к континууму, в связи с изменяющимся кулоновским полем.

В данной работе расчитаны энергетические уровни гало ядра ^{11}Be , с учетом влияния внешнего магнитного поля, т.е. вычислено расщепление энергетических уровней численным и аналитическим методами с использованием двух разных потенциалов:в форме Вудс-Саксона и Гаусса. Ядро ^{11}Be, имеющее как нейтронное гало, состоящий из кора ^{10}Be и одного нейтрона. Эта работа является начальным этапом работы по исследованию развала гало ядер в кванто-механическом подходе.

Ключевые слова: гало ядро, кулоновский развал, сечение развала, экзотические состояния ядер, стационарное уравнение Шредингера, энергетический спектр, ядерный потенциал.

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BOUNDARY VALUE PROBLEM FOR ELASTIC HALF-SPACE BY SUBSONIC VELOCITIES OF SURFACE TRANSPORT LOADS MOVING

Abstract. The first boundary value problem of the theory of elasticity for an elastic half-space at the movement on its surface of subsonic trans loads is considered. The speed of motion is less or more than the speed of distribution of elastic Rayleigh waves. On the basis of the generalized Fourier's transformation the fundamental solution of a task is constructed which describes dynamics of the massif at the movement of the concentrated force on and along its surface. Based on this, an analytical solution is constructed for arbitrary transport loads distributed over the surface, moving with the pre- Rayleigh and super-Rayleigh velocities. It is shown that when the Rayleigh wave velocity is exceeded, the transport loads generate surface Rayleigh waves.

The task is a model for research of the intense deformed condition of the pedigree massif in the vicinity of road constructions at moving transport.

Keywords: boundary value problem, an elastic half-space, trans loading, subsonic speed, Rayleigh wave, the stress-strain state.

Trans loads are very widespread in practice. As those we understand the moving loads which form doesn't change over time, but their position are changing in the environment. Dynamic deformation processes, which arise in the ground under their influence, expand with different speeds, characterizing elastic properties of the medium. In isotropic elastic medium there are two sound speeds of expansion of *dilatation waves* (c_1) and *shift* (c_2) *waves* ($c_{1>}c_2$). The relation of speed of trans load to the sound velocities significantly influences to the stresses and deformations in the elastic medium. We consider here the subsonic case, when speeds of loads are less then shift waves speed. This case is characteristic for trans problems as the speed of the movement of the most modern vehicles is many less then the speeds of elastic waves propagation. From trans loads we especially distinguish stationary ones which move in the fixed direction with a constant speed (*transport loads*). This class of loads allows to investigate diffraction processes in isotropic elastic medium in analytical form.

In papers [1-3] the fundamental and generalized solutions of the Lame's equations are constructed and investigated which describe the movement of elastic medium at the action of concentrated on an axis and distributed loading in all range of speeds (subsonic, sound, transonic and supersonic ones). On this basis in [4-7] the method of boundary integral equations has been developed for solving the transport BVP in elastic medium with cylindrical boundaries. This class of problems is very important for applications in the field of dynamics of underground constructions, trans tunnels and excavations of deep laying.

However there is a class of model trans tasks (for example, road problems) when loadings move on the surface of a half-space. It is known that there is also sound speed in an elastic half-space with which superficial Rayleigh waves are propagating. The Rayleigh's speed is less, but is very close to the speed of shift waves [10,11]. Rayleigh's waves don't create tensions on half-space border, but significantly influence on the tensions and deformations of the massif near a free surface.

For the first time such task was considered and solved for a subsonic pre-Ryleigh case by flat deformation in work [8]. Here the analytical solution of this task in three-dimensional statement is constructed also in a subsonic case, when the speed of subsonic trans load is less or more than the Rayleigh's speed.

1. **The statement of transport boundary value problem for elastic half-space**

Elastic isotropic medium, with Lame's parameters λ,μ and the density ρ, occupies half-plane $x_1 > 0$, ***n*** (x)=(-1,0, 0) is unit vector of the external normal to its boundary $D = \left\{ x \in R^3 : x_1 = 0 \right\}$. Constants c_1 and c_2 are the velocities of elastic waves propagation [11]:

$$c_1 = \sqrt{\frac{\lambda + 2\mu}{\rho}}, \quad c_2 = \sqrt{\frac{\mu}{\rho}}, \quad c_2 < c_1 \ (\textit{sonic speeds}):$$

Boundary transport load $\mathbf{P}(x,t)$ are moving with constant subsonic speed ($c < c_2 < c_1$) along the axis X_3: $\mathbf{P}(x,t) = \mu p_j(x_2, x_3 + ct)e_j$. Components of stress tensor σ_{ij} are connected with medium displacements $u(x,t)$ by Hook's law:

$$\sigma_{ij} = \lambda \operatorname{div} u \, \delta_{ij} + \mu (u_{i,j} + u_{j,i}) \ .$$

For dynamics problems this law better to write in the unitless form:

Hook's law:

$$\frac{\sigma_{ij}}{\mu} = \left(\frac{c_1^2}{c_2^2} - 2 \right) \operatorname{div} u \, \delta_{ij} + (u_{i,j} + u_{j,i}) \tag{1}$$

Here and everywhere further on the identical indexes the tensor convolution have been made. Private derivatives on the corresponding coordinate are designated by the index after comma: $u_{i,j} = \frac{\partial u_i}{\partial x_j}$; $\delta_{ij} = \delta_i^j$ is Kronecker symbol.

The stationary movement has been considered that allows to pass into mobile coordinates system which are connected with transport load. Further we use designations: $x = (x_1, x_2)$, $z = x_3 + ct$.

It's supposed that components of the load allow the Fourier's transformation, i.e. they are representable in the form of Fourier's integrals:

$$\begin{gathered} P_j(x_2,z) = \sigma_{j1}(0,x_2,z) = \frac{\mu}{(2\pi)^2} \int_{R^2} \overline{p}_n(\eta,\varsigma) \exp(-i(x_2\eta + \zeta z)) d\eta d\varsigma \\ \overline{p}_n(\eta,\varsigma) = \int_{R^2} p_n(x_2,z) \exp(i(x_2\eta + z\varsigma)) dx_2 dz \end{gathered} \tag{2}$$

The Lame's equations for displacements of elastic half-space in mobile coordinates system have the form [1]:

$$\left(\left(M_1^{-2} - M_2^{-2} \right) \frac{\partial^2}{\partial x_i \partial x_j} + \left(M_2^{-2} \Delta - (\partial_z)^2 \right) \delta_i^j \right) u_j = 0 \tag{3}$$

This operator we denote L_{ij} ($\partial_1, \partial_2, \partial_z$). Here two Mach's numbers are introduced:

$$M_1 = c / c_1, \quad M_2 = c / c_2 ,$$

which characterize the velocity of transport load in relation to the sound speeds of elastic waves.

Eqs. (3) were studied in [2,3]. There are three cases: subsonic $(c < c_2)$, transonic $(c_2 < c < c_1)$, supersonic $(c > c_1)$ and two sonic cases $(c = c_2, c = c_1)$. In the first case $(M_1 < 1,\ M_2 < 1)$ the system (3) is elliptic, in the second one $(M_1 < 1,\ M_2 > 1)$ it has have the mixed elliptic-hyperbolic type. In supersonic case $(M_1 > 1,\ M_2 > 1)$ this system is strong hyperbolic. By sonic speeds it is mixed parabolic-elliptic if $M_1 < 1,\ M_2 = 1$, and it's hyperbolic-parabolic if $M_1 = 1,\ M_2 > 1$.

By sonic and supersonic velocities the shock waves can appear in elastic medium. There are the next conditions on the jumps on their fronts *F*:

$$\left[u_j\right]_F = 0 \quad \Rightarrow \quad h_z\left[u_{i},_j\right]_F = h_j\left[u_{i},_z\right]_F;$$
$$h_j\left[\sigma_{ij}\right]_F = \rho c^2 h_z\left[u_{i},_z\right]_F, \quad i,j = 1,2,3. \tag{4}$$

Here $h(x_1, x_2, z) = (h_1, h_2, h_3 \,\square\, h_z)$ is wave vector, $\|h\| = 1$. It's perpendicular to a front F in the direction of wave propagation. The continuity of elastic medium gives the first condition. The second condition is continuity of tangent derivatives at the front of a wave; it is consequence from the first one. The third formula is law of momentum conservation on waves fronts.

Here we consider the subsonic case. It's required to find the solution of the BVP which must to satisfy

the attenuation condition on infinity:

$u \to 0$ by $x_1 \to +\infty$ or $z \to \pm\infty$. (5)

Also we'll enter later some additional *radiation conditions* by construction of BVP solution.

1. Green tensor of transport BVP

To solve the problem, we construct the Green's tensor Π_j^k of the boundary value problem in a moving coordinates system. For its determination we have the following boundary value problem.

To find the tensor solution of homogeneous motion equations :

$$\left(\left(M_1^{-2} - M_2^{-2}\right)\frac{\partial^2}{\partial x_i \partial x_j} + \left(M_2^{-2}\Delta - \frac{\partial^2}{\partial z^2}\right)\delta_i^j\right)\Pi_j^k = 0, \quad i,j,k = 1,2,3, \tag{6}$$

in the region $x_1 > 0$, which must to satisfy the attenuation condition at infinity:

$$\Pi_j^k(x,z) \to 0 \ \text{for} \ \|(x,z)\| \to 0 \ . \tag{7}$$

Corresponding stress tensor Σ_{jk}^m , which are calculated by use Hooh's law (2), has the form:

$$\Sigma_{jk}^m = \alpha\Pi_l^m,_l\,\delta_{jk} + (\Pi_j^m,_k + \Pi_k^m,_j) = S_{jk}^l(\partial_1,\partial_2,\partial_z)\Pi_l^m(x_1,x_2,z),$$
$$S_{jk}^l = \alpha\delta_{jk}\partial_l + (\delta_{jl}\partial_k + \delta_{lk}\partial_j) \tag{8}$$

T h e o r e m. *The solution of the given boundary-value problem has the form of the following convolution on the boundary of a half-space*

$$u_j(x_1,x_2,z) = \int_{R^q}^{\infty}\Pi_j^n(x_1, x_2 - y_2, z - y_3)\,p_n(y_2,y_3)\,dy_2 dy_3, \quad j = 1,2,3. \tag{9}$$

and must satisfy to the following singular conditions on the free surface : *for* x_1=0

$$\Sigma_{i1}^m = \alpha\Pi_k^m,_k\,\delta_{i1} + (\Pi_i^m,_1 + \Pi_1^m,_i) = \delta_i^m\delta(x_2)\delta(z), \quad i,m,k = 1,2,3. \tag{10}$$

where $\delta(x_j)$ *is generalized Dirac function,* $\alpha = \dfrac{\lambda}{\mu} = \left(\dfrac{c_1^2}{c_2^2} - 2\right) = \left(\dfrac{M_2^2}{M_1^2} - 2\right)$.

P r o o f. Indeed, by virtue of (1), (10) and the convolution properties we have on the boundary of the half-space:

$$\int_{R^q}^{\infty} \Sigma_{j1}^{m}(0, x_2 - y_2, z - y_3)\, p_m(y_2, y_3)\, dy_2 dy_3 = \delta_j^m \delta(x_2)\delta(z) * p_m(x_2, z) = p_j(x_2, z).$$

Here on the right there is a functional convolution along the half-space boundary and tensor convolution by the index *m*. The displacements (9) satisfy to the homogeneous transport Lame equations (3) in the half-space:

$$L_i^j(\partial_1, \partial_2, \partial_z)u_j = \int_{R^q}^{\infty} p_n(y_2, y_3) L_i^j(\partial_1, \partial_2, \partial_z)\Pi_j^n(x_1, x_2 - y_2, z - y_3)\, dy_2 dy_3 = 0$$

in view of (6) and the invariance of these equations with respect to the shift at the boundary of the half-space

This tensor $\Pi(x, z)$ gives possibility to use the formula (9) for determination of displacements in a half-space for any loading on its surface. The stresses at any point of the elastic half-space on the area with the normal *n* are determined by the formula

$$\begin{aligned} S(x_1, x_2, z, n) &= \sigma_{jk}(x_1, x_2, z) n_j e_k = \\ &= \mu e_k n_j \int_{R^q}^{\infty} \Sigma_{kj}^{l}(x_1, x_2 - y_2, z - y_3)\, p_l(y_2, y_3)\, dy_2 dy_3. \end{aligned} \tag{11}$$

Thus, the definition of the fundamental displacement tensor determines the solution of the problem.

We construct the tensor $\Pi(x, z)$ using the scalar and vector elastic Lame potentials.

2. Statement of the transport problem for Lame's potentials

The displacements of the elastic medium can be represented in terms of the scalar and vector Lame's potentials [1,11]:

$$u = grad\,\varphi + rot\,\psi \tag{12}$$

Since the three components of the displacements are determined through four potential components, the vector potential is usually associated with a Gaussian or Lorentz gauge. Here it is convenient to use the representation:

$$\psi = \psi_1 e_3 + rot(\psi_2 e_3),$$

which uniquely links the three components of displacements with three potentials. If the displacements satisfy to the homogeneous Lame equations, then the potentials satisfy the d'Alembert's wave equation with the corresponding velocity:

$$\begin{gathered} c_1^2 \Delta\varphi - \frac{\partial^2 \varphi}{\partial t^2} = 0, \\ c_2^2 \Delta\psi_k - \frac{\partial^2 \psi_k}{\partial t^2} = 0, \quad k = 1,2 \end{gathered} \tag{12}$$

where Δ is Laplace operator. In the moving coordinate system these equations are transformed to the form:

$$\begin{gathered} \Delta\varphi - M_1^2 \frac{\partial^2 \varphi}{\partial z^2} = 0, \\ \Delta\psi_k - M_2^2 \frac{\partial^2 \psi_k}{\partial z^2} = 0, \quad k = 1,2 \end{gathered} \tag{13}$$

To construct the tensor Π^i_j , we use similar potentials. Namely, we represent it in the form

$$\begin{gathered}\Pi^m_k(x_1,x_2,z)=D_{kn}(\partial_1,\partial_2,\partial_z)\Phi^m_n=\partial_k\Phi^m_1+e_{ki3}\partial_i\Phi^m_2+e_{kjl}e_{li3}\partial_j\partial_i\Phi^m_3\\ D_{k1}(\partial_1,\partial_2,\partial_z)=\partial_k\\ D_{k2}(\partial_1,\partial_2,\partial_z)=e_{ki3}\partial_i\\ D_{k3}(\partial_1,\partial_2,\partial_z)=e_{kjl}e_{li3}\partial_i\partial_j\end{gathered}\tag{14}$$

Here i,j,k,l,m=1,2,3, e_{ijk} is Levi-Civita pseudotensor. The first potential describes the gradient component of the displacements field, and the other two potentials describe the rotor (solenoidal) components . The potentials satisfy to the

transport wave equations:

$$\Delta\Phi^m_j-M_j^2\frac{\partial^2\Phi^m_j}{\partial z^2}=0,\quad j=1,2,3.\tag{15}$$

We name them *fundamental potentials.* To calculate them we use boundary conditions (9) :

by $x_1=0$

$$\alpha\,\Pi^m_{k},_k\delta_{i1}+(\Pi^m_i,_1+\Pi^m_1,_i)=\delta^m_i\delta(x_2)\delta(z)$$

where

$$\begin{gathered}\Pi^m_k,_k=\Delta\Phi^m_1+e_{ki3}\partial_k\partial_i\Phi^m_2+e_{kjl}e_{li3}\partial_k\partial_i\partial_j\Phi^m_3\,,\\ \Pi^m_i,_1=\partial_i\partial_1\Phi^m_1+e_{ik3}\partial_k\partial_1\Phi^m_2+e_{ijl}e_{lk3}\partial_k\partial_j\partial_1\Phi^m_3\,,\\ \Pi^m_1,_i=\partial_i\partial_1\Phi^m_1+e_{1k3}\partial_k\partial_i\Phi^m_2+e_{1jl}e_{lk3}\partial_k\partial_j\partial_i\Phi^m_3\,,\end{gathered}$$

We can to write it in the form:

$$\mathrm{B}_{in}(\partial_1,\partial_2,\partial_z)\Phi^m_n=\delta^m_i\delta(x_2)\delta(z),\quad n,m=1,2,3,\tag{16}$$

where

$$\begin{gathered}\mathrm{B}_{in}\Phi^m_n=\left[2\partial_i\partial_1\Phi^m_1+\partial_k\left\{\left(e_{ik3}\partial_1+e_{1k3}\partial_i\right)\Phi^m_2+\partial_j\left(e_{ijl}e_{lk3}\partial_1+e_{1jl}e_{lk3}\partial_i\right)\Phi^m_3\right\}\right]+\\ +\alpha\left[\Delta\Phi^m_1+e_{kj3}\partial_k\partial_j\Phi^m_2+e_{kjl}e_{ls3}\partial_k\partial_s\partial_j\Phi^m_3\right]\delta_{i1}\Rightarrow\\ \mathrm{B}_{in}(\partial_1,\partial_2,\partial_z)\Phi^m_n=\left(\alpha\delta_{i1}\Delta+2\partial_1\partial_i\right)\Phi^m_1+\partial_k\left(\alpha\delta_{i1}e_{kj3}\partial_j+e_{ik3}\partial_1+e_{1k3}\partial_i\right)\Phi^m_2+\\ +\partial_k\partial_j\left\{\alpha\delta_{i1}e_{kjl}e_{ls3}\partial_s+\left(e_{ijl}e_{lk3}\partial_1+e_{1jl}e_{lk3}\partial_i\right)\right\}\Phi^m_3=\\ =\left(\alpha M_1^2\delta_{i1}\partial_z\partial_z+2\partial_1\partial_i\right)\Phi^m_1+\partial_k\left(\alpha\delta_{i1}e_{kj3}\partial_j+e_{ik3}\partial_1+e_{1k3}\partial_i\right)\Phi^m_2+\\ +\partial_k\partial_j\left\{\alpha\delta_{i1}e_{kjl}e_{ls3}\partial_s+\left(e_{ijl}e_{lk3}\partial_1+e_{1jl}e_{lk3}\partial_i\right)\right\}\Phi^m_3\end{gathered}$$

This implies

$$\begin{gathered}\mathrm{B}_{i1}(\partial_1,\partial_2,\partial_z)=\left(\alpha M_1^2\delta_{i1}\partial_z\partial_z+2\partial_1\partial_i\right),\\ \mathrm{B}_{i2}(\partial_1,\partial_2,\partial_z)=\partial_k\left(\alpha\delta_{i1}e_{kj3}\partial_j+e_{ik3}\partial_1+e_{1k3}\partial_i\right)\\ \mathrm{B}_{i3}(\partial_1,\partial_2,\partial_z)=\partial_k\partial_j\left\{\alpha\delta_{i1}e_{kjl}e_{ls3}\partial_s+\left(e_{ijl}e_{lk3}\partial_1+e_{1jl}e_{lk3}\partial_i\right)\right\}\end{gathered}$$

Using the properties of the permutation of the indices of the Levi-Civita tensor and the formula for its convolution:

$$e_{lij}e_{lkm}=\delta_{ik}\delta_{jm}-\delta_{im}\delta_{kj}\,,$$

these operators can be greatly simplified:

$$\mathrm{B}_{11}(\partial_1,\partial_2,\partial_z)=\left(\alpha M_1^2\partial_z^2+2\partial_1^2\right),$$

$$\mathrm{B}_{21}(\partial_1,\partial_2,\partial_z)=2\partial_1\partial_2,\quad \mathrm{B}_{31}(\partial_1,\partial_2,\partial_z)=2\partial_1\partial_3,$$

$$\mathrm{B}_{12}(\partial_1,\partial_2,\partial_z)=\partial_k\left(\alpha e_{kj3}\partial_j+e_{1k3}\partial_1+e_{1k3}\partial_1\right)=\left(\alpha e_{kj3}\partial_k\partial_j+2\partial_1\partial_2\right)=$$

$$=\alpha\left(e_{123}\partial_1\partial_2+e_{213}\partial_2\partial_1\right)+2\partial_1\partial_2=2\partial_1\partial_2\ ,$$

$$\mathrm{B}_{22}(\partial_1,\partial_2,\partial_z)=\partial_k\left(\alpha\delta_{21}e_{kj3}\partial_j+e_{2k3}\partial_1+e_{1k3}\partial_2\right)=$$

$$=\left(e_{213}\partial_1\partial_1+e_{123}\partial_2\partial_2\right)=\partial_2\partial_2-\partial_1\partial_1,$$

$$\mathrm{B}_{32}(\partial_1,\partial_2,\partial_z)=\partial_k\left(e_{3k3}\partial_1+e_{1k3}\partial_3\right)=\partial_2\partial_3,$$

$$\mathrm{B}_{13}(\partial_1,\partial_2,\partial_z)=\partial_k\partial_j\left\{\alpha e_{kjl}e_{lm3}\partial_m+\left(e_{1jl}e_{lk3}\partial_1+e_{1jl}e_{lk3}\partial_1\right)\right\}=$$

$$=\alpha\left(\delta_{km}\delta_{j3}-\delta_{kj}\delta_{m3}\right)\partial_k\partial_j\partial_m+\left(\delta_{1k}\delta_{j3}-\delta_{13}\delta_{jk}\right)\partial_1\partial_k\partial_j+$$

$$+\left(\delta_{1k}\delta_{j3}-\delta_{13}\delta_{jk}\right)\partial_1\partial_k\partial_j=\alpha\left(\partial_3\partial_m\partial_m-\partial_3\partial_j\partial_j\right)+2\partial_1\partial_1\partial_3=2\partial_1\partial_1\partial_3,$$

$$\mathrm{B}_{23}(\partial_1,\partial_2,\partial_z)=e_{2jl}e_{lk3}\partial_1\partial_k\partial_j+e_{1jl}e_{lk3}\partial_2\partial_k\partial_j=$$

$$=\left(\delta_{2k}\delta_{j3}-\delta_{23}\delta_{jk}\right)\partial_1\partial_k\partial_j+\left(\delta_{1k}\delta_{j3}-\delta_{13}\delta_{jk}\right)\partial_2\partial_k\partial_j=2\partial_1\partial_2\partial_3,$$

$$\mathrm{B}_{33}(\partial_1,\partial_2,\partial_z)=e_{2jl}e_{lk3}\partial_1\partial_k\partial_j+e_{1jl}e_{lk3}\partial_2\partial_k\partial_j=$$

$$=\left(\delta_{2k}\delta_{j3}-\delta_{23}\delta_{kj}\right)\partial_1\partial_k\partial_j+\left(\delta_{1k}\delta_{j3}-\delta_{13}\delta_{jk}\right)\partial_2\partial_k\partial_j=2\partial_1\partial_2\partial_3.$$

As a result, we get:

$$\begin{gathered}\mathrm{B}_{11}=\left(\alpha M_1^2\partial_z\partial_z+2\partial_1^2\right),B_{12}=2\partial_1\partial_2,\quad B_{13}=2\partial_1^2\partial_3,\\ \mathrm{B}_{21}(\partial_1,\partial_2,\partial_z)=2\partial_1\partial_2,\quad \mathrm{B}_{22}(\partial_1,\partial_2,\partial_z)=\partial_2\partial_2-\partial_1\partial_1,\quad \mathrm{B}_{23}(\partial_1,\partial_2,\partial_z)=2\partial_1\partial_2\partial_3,\\ \mathrm{B}_{31}(\partial_1,\partial_2,\partial_z)=2\partial_1\partial_3,\quad \mathrm{B}_{32}(\partial_1,\partial_2,\partial_z)=2\partial_3\partial_2,\quad \mathrm{B}_{33}(\partial_1,\partial_2,\partial_z)=2\partial_1\partial_2\partial_3.\end{gathered}\tag{17}$$

Thus, the problem of constructing the transformants of the unknown tensors reduces to determining the Lamé potentials satisfying equations (14), the boundary conditions on the free surface (16), and the damping conditions at infinity:

$$\Phi_j^k\to 0\ \text{by}\ \|(x,z)\|\to\infty\ ,\tag{18}$$

and certain radiation conditions, which we discuss below.

3. Determination of Fourier transforms of fundamental potentials

To construct the solution, we use the Fourier transform of the potentials with respect to x_2,z. In the space of Fourier transforms, they correspond to variables η,ζ. Their Fourier transforms are defined by the relations:

$$\overline{\Phi}^m=\int_{R^2}\Phi^m(x,z)\exp(i\eta x_2+i\zeta z)dzdx_2\ ,\ \Phi^m=\frac{1}{4\pi^2}\int_{R^2}\overline{\Phi}^m(x,\eta,\varsigma)\exp(-i\eta x_2-i\zeta z)d\varsigma d\eta$$

In the space of Fourier transforms the equations for the potentials (14) have the form:

$$\frac{d^2\bar{\Phi}_j^m}{dx_1^2}-\eta^2\overline{\Phi}_j^m-\alpha_j^2\zeta^2\overline{\Phi}_j^m=0,\quad \alpha_j=\sqrt{1-M_j^2}\ ,\ j=1,2,3.\tag{19}$$

The expression under radical is positive, because we consider the subsonic case. The boundary conditions are transformed to the form:

$$\mathrm{B}_{ik}(\partial_1,-i\eta,-i\varsigma)\overline{\Phi}_k^m(x_1,\eta,\zeta)=\delta_i^m \text{ by } x_1=0. \tag{20}$$

Conditions for damping at infinity: for $\forall\eta,\zeta$

$$\overline{\Phi}_k^m(x_1,\eta,\zeta)\to 0 \text{ by } x_1\to\infty. \tag{21}$$

By these conditions the solution of Eq. (19) has the form:

$$\overline{\Phi}_j^k=\varphi_j^k(\eta,\varsigma)\exp\left(-x_1\sqrt{\eta^2+\alpha_j^2\zeta^2}\right),\ \mathrm{Re}\sqrt{\eta^2+\alpha_j^2\zeta^2}\ge 0. \tag{22}$$

Functions $\varphi_j^k(\eta,\varsigma)$ are determined from boundary conditions (19) :

$$\sum_{j=1}^{3}\mathrm{B}_{in}(-\sqrt{\eta^2+\alpha_j^2\zeta^2},-i\eta,-i\zeta)\varphi_n^m=\delta_i^m,\ k=1,2,3 \tag{23}$$

Thus, for each fixed m, we have the linear system of three equations for determination φ_k^m, from which we find

$$\varphi_j^m=\frac{\Delta_j^m(\eta,\zeta)}{\Delta(\eta,\zeta)}. \tag{24}$$

Here Δ_j^m is corresponding algebraic complement, and the denominator is equal to

$$\Delta(\eta,\zeta)=\det\{\mathrm{B}_{kj}(-\sqrt{\eta^2+\alpha_j^2\zeta^2},-i\eta,-i\zeta)\}.$$

This is a well-known Rayleigh determinant. In this case it has the form:

$$\Delta=4\nu^2\sqrt{\nu^2-M_1^2\zeta^2}\sqrt{\nu^2-M_2^2\zeta^2}-(2\nu^2-M_2^2\zeta^2)^2,\ \nu^2=\zeta^2+\eta^2. \tag{25}$$

The properties of Rayleigh determinant are known. For transport problems, it was well studied in [1]. In particular,

$$\Delta(\eta,\zeta)=0$$

$$\text{by } \eta=\eta_R^{\pm}(\varsigma)=\pm|\zeta|\sqrt{M_R^2-1}\quad\Leftrightarrow\quad\varsigma=\zeta_R^{\pm}(\eta)=\pm\frac{|\eta|}{\sqrt{M_R^2-1}} \tag{26}$$

where $M_R=c/c_R$, c_R is the velocity of the surface Rayleigh wave, which is subsonic ($c_R<c_2$). It can be determined from the equation:

$$4\sqrt{1-m_1^2}\sqrt{1-m_2^2}-(2-m_2^2)^2=0,\ m_j=c_R/c_j \tag{27}$$

Formulae (22), (24) formally resolve the problem in the potentials. However, in order to reconstruct the originals, it is necessary to investigate the properties of the transformants - integrand functions in (18), which essentially depend on the speed of a transport load.

6. Restoration of originals Π_k^m and Σ_{jk}^m by pre-Releygh speed *c*

From (14) we get

$$\overline{\Pi}_k^m=D_{kn}(\partial_1,-i\eta,-i\varsigma)\overline{\Phi}_n^m(x_1,\eta,\varsigma)=\frac{\Delta_n^m(\eta,\zeta)}{\Delta(\eta,\zeta)}D_{kn}(\partial_1,-i\eta,-i\varsigma)\exp\left(-x_1\sqrt{\eta^2+\alpha_n\varsigma^2}\right)\Rightarrow$$

$$\overline{\Pi}_k^m=\frac{\Delta_n^m(\eta,\zeta)}{\Delta(\eta,\zeta)}D_{kn}(-\sqrt{\eta^2+\alpha_n\varsigma^2},-i\eta,-i\varsigma)\exp\left(-x_1\sqrt{\eta^2+\alpha_n\varsigma^2}\right) \tag{28}$$

$$\overline{\Pi}_k^m(x_1,\eta,\zeta)=D_{kn}(-\sqrt{\eta^2+\alpha_j^2\zeta^2},-i\eta,-i\zeta)\varphi_n^m(x_1,\eta,\zeta)\exp(-x_1\sqrt{\eta^2+\alpha_n^2\zeta^2}) \qquad (28)$$

Using the inverse Fourier transform, we obtain

$$\Pi_k^m(x_1,x_2,z)=(2\pi)^{-2}\int_{R^2}\overline{\Pi}_k^m(x_1,\eta,\zeta)\exp(-i(\eta x_2+\zeta z))d\varsigma d\eta=$$

$$=(2\pi)^{-2}\int_{R^2}D_{kn}(-\sqrt{\eta^2+\alpha_j^2\zeta^2},i\eta,i\zeta)\varphi_n^m(\eta,\zeta)\exp(-x_1\sqrt{\eta^2+\alpha_j^2\zeta^2}-i\eta x_2-i\zeta z)d\varsigma d\eta= \qquad (29)$$

$$=(2\pi)^{-2}\int_{R^2}\frac{D_{kn}(-\sqrt{\eta^2+\alpha_j^2\zeta^2},i\eta,i\zeta)\Delta_n^m(\eta,\zeta)}{\Delta(\eta,\zeta)}\exp(-x_1\sqrt{\eta^2+\alpha_j^2\zeta^2}-i\eta x_2-i\zeta z)d\varsigma d\eta$$

Let us calculate the fundamental stresses and their transformants. For this, we use the formulas (10), from which we obtain

$$\Sigma_{jk}^m=\lambda\Pi_{l},_l^m\delta_{jk}+\mu(\Pi_{j},_k^m+\Pi_{k},_j^m)=S_{jk}^l(\partial_1,\partial_2,\partial_z)\Pi_l^m=$$

$$=S_{jk}^l(\partial_1,\partial_2,\partial_z)D_{ln}(\partial_1,\partial_2,\partial_z)\Phi_n^m(x_1,x_2,z)=T_{jkn}(\partial_1,\partial_2,\partial_z)\Phi_n^m(x_1,x_2,z), \qquad (30)$$

$$T_{jkn}=S_{jk}^l(\partial_1,\partial_2,\partial_z)D_{ln}(\partial_1,\partial_2,\partial_z)$$

Hence we get

$$\overline{\Sigma}_{jk}^m=T_{jkn}(-\sqrt{\eta^2+\alpha_n\varsigma^2},-i\eta,-i\varsigma)\hat{\Phi}_n^m(x_1,\eta,\varsigma)=$$

$$=T_{jkn}(-\sqrt{\eta^2+\alpha_n\varsigma^2},-i\eta,-i\varsigma)\frac{\Delta_n^m(\eta,\zeta)}{\Delta(\eta,\zeta)}\exp\left(-x_1\sqrt{\eta^2+\alpha_n\varsigma^2}\right)$$

The original of the stress tensor in any point (x, z) is calculated by use the formula

$$\Sigma_{jk}^m(x_1,x_2,z)=(2\pi)^{-2}\int_{R^2}\overline{\Sigma}_{jk}^m(x_1,\eta,\zeta)\exp(-i(\eta x_2+\zeta z))d\varsigma d\eta. \qquad (31)$$

For $c<c_R$ the determinant $\Delta(\eta,\zeta)\neq 0$ for any real ζ,η. That is, at the pre-Releygh velocities all the integrands are continuous and tend exponentially to zero when (η,ζ) tends to infinity. Therefore, the integrals exist and satisfy the damping conditions at infinity.

When $x_1=0,\ (x_2,z)\neq(0,0),$ the integrands in (29) and (31) are also continuous and integrable, since they are oscillating and have the order of damping not lower $O\left((\eta^2+\varsigma^2)^{-1}\right)$.

7. Determination of displacements and stresses at pre-Rayleigh speeds of transport load

To calculate the displacements of the medium for arbitrary transport load, we find the Fourier transform of the displacements. According to (9) and the convolution properties

$$\bar{u}_j(x_1,\eta,\zeta)=\mathrm{F}_{x_2,z}[u_j(x_1,x_2,z)]=\overline{\Pi}_j^n(x_1,\eta,\varsigma)\bar{p}_n(\eta,\varsigma). \qquad (32)$$

Substituting it in (28), we have

$$\bar{u}_k(x_1,\eta,\zeta)=\frac{\bar{p}_m(\eta,\varsigma)\Delta_n^m(\eta,\zeta)}{\Delta(\eta,\zeta)}D_{kn}(-\sqrt{\eta^2+\alpha_n\varsigma^2},-i\eta,-i\varsigma)\exp\left(-x_1\sqrt{\eta^2+\alpha_n\varsigma^2}\right)$$

Returning to the original, we obtain formulas for calculating the displacements at pre-Rayleigh speeds:

$$u_k(x_1,x_2,z)=\frac{1}{4\pi^2}\iint_{R^2}\overline{u}_k(x_1,\eta,\zeta)\exp(-i(x_2\eta+z\varsigma))d\eta d\varsigma$$

To determine the stresses, we use the formula (11), which for the Fourier transforms has the type:

$$\sigma_{kj}(x_1,x_2,z)=\frac{1}{4\pi^2}\int_{R^2}\overline{\Sigma}_{kj}^{n}(x_1,\eta,\zeta)\overline{p}_n(\eta,\varsigma)\exp(-i(x_2\eta+z\varsigma))d\eta d\zeta.$$

At pre-Rayleigh velocities in formulas (31) and (32), all the integrands are continuous and tend exponentially to zero by $x_1\to\infty$. Therefore, the integrals exist and satisfy the damping conditions at infinity. The asymptotic behavior of displacements at infinity is determined by the asymptotic of the transport load on the surface of the half-space.

6. Construction of Green tensor Π_k^m at super-Rayleigh speed ($c_R<c<c_2$)

If subsonic speed c is more then Rayleigh speed c_R then for constructing the solution we transform contour of integration in the ε-vicinity of point $\zeta_R(\eta)$ by any fixed η by way of moving along the circle of radius ε in upper half-plane of complex ζ by z>0 and in under half-plane by z<0 to get under sign of integral the waves, which tend to zero by $|z|\to\infty$. If $\varepsilon\to 0$, then, with use the theorem on residue of complex analysis, we get Green tensor in the form:

$$4\pi^2\Pi_k^m(x_1,x_2,z)=$$

$$=\int_{-\infty}^{\infty}\left\{\text{V.P.}\int_{-\infty}^{\infty}\sum_{j=1}^{3}D_{kn}(-\sqrt{\eta^2+\alpha_j^2\zeta^2},i\eta,i\zeta)\frac{\Delta_n^m(\eta,\zeta)}{\Delta(\eta,\zeta)}\exp(-x_1\sqrt{\eta^2+\alpha_j^2\zeta^2}-i\zeta z)d\varsigma\right\}e^{-i\eta x_2}d\eta- \qquad (33)$$

$$-i\pi\,\mathrm{sgn}\,z\sum_{\pm}\int_{-\infty}^{\infty}\sum_{j=1}^{3}D_{kn}\left(-|\eta|\sqrt{\frac{M_R^2-M_j^2}{M_R^2-1}},i\eta,i\zeta_R^{\pm}\right)\frac{\Delta_n^m(\eta,\zeta_R^{\pm})}{\Delta_\zeta(\eta,\zeta_R^{\pm}(\eta))}\exp\left(-x_1|\eta|\sqrt{\frac{M_R^2-M_j^2}{M_R^2-1}}\right)e^{-i(\eta x_2+z\zeta_R^{\pm}(\eta))}d\eta$$

Here to calculate the Value Principle integral we can use the formula:

$$\text{V.P.}\int_{-\infty}^{\infty}D_{kn}(-\sqrt{\eta^2+\alpha_j^2\zeta^2},i\eta,i\zeta)\frac{\Delta_n^m(\eta,\zeta)}{\Delta(\eta,\zeta)}\exp(-x_1\sqrt{\eta^2+\alpha_j^2\zeta^2}-i\zeta z)d\varsigma=$$

$$=\int_0^{\infty}\left(\Upsilon_{kn}^m(x_1,z,\eta,\varsigma)+\Upsilon(x_1,z,\eta,-\varsigma)\right)\exp(-x_1\sqrt{\eta^2+\alpha_j^2\zeta^2})d\varsigma,$$

$$\Upsilon_{kn}^m(x_1,z,\eta,\varsigma)=D_{kn}(-\sqrt{\eta^2+\alpha_j^2\zeta^2},i\eta,i\zeta)\frac{\Delta_n^m(\eta,\zeta)e^{-i\zeta z}}{\Delta(\eta,\zeta)}$$

The last integral doesn't have singularities in Rayleigh's points and can be calculated numerically.

The second summand in formula (33) describes the surface Rayleigh waves, which are generated by transport load when $c_R<c<c_2$.

By $c=c_R$ the stationary solution of this problem doesn't exist.

Conclusion. Here presented solutions of boundary value problems are very useful for applications when assessing the impact of road trans on the environment. It allows to determine the stress-strain state of the rock massif, depending on its elastic properties, the type of the acting load and the speed of the vehicle. This is especially true now with the development of high-speed road and rail trans, the speed of which can have a devastating impact on the surrounding areas. The obtained solutions allow us to determine the range of possible speeds of movement, taking into account the strength properties of the rock massif and the road surface, which makes it possible to ensure the safety and reliability of operation of modern vehicles.

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КРАЕВАЯ ЗАДАЧА ДЛЯ УПРУГОГО ПОЛУПРОСТРАНСТВА ПРИ ДОЗВУКОВЫХ СКОРОСТЯХ ДВИЖЕНИЯ ПОВЕРХНОСТНОЙ НАГРУЗКИ

Аннотация. Рассматривается первая краевая задача теории упругости для упругого полупространства при движении по его поверхности транспортной нагрузки со скоростью, меньшей, чем скорость распространения упругих волн. На основе обобщенного преобразования Фурье построен тензор Грина - фундаментальное решение задачи, описывающее динамику массива при движении сосредоточенной силы по его поверхности. На его основе построено аналитическое решение для произвольных распределенных по поверхности транспортных нагрузок, движущихся с дорелеевской и сверхрелеевской скоростью. Показано, что при превышении скорости волны Релея транспортные нагрузки генерируют поверхностные релеевские волны.

Задача является модельной для исследования напряженно-деформированного состояния породного массива в окрестности дорожных сооружений при движущемся транспорте.

Ключевые слова: упругое полупространство, транспортная нагрузка, дозвуковая скорость, волны Релея, напряженно-деформированное состояние.

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APPLIANCE OF FLOYD WARSHALL, BELLMAN-FORD ALGORITHMS FOR ADDING NOISE PERMUTATIONS OF BLOCK CIPHERS FOR CRYPTOGRAPHIC ENDURANCE ENHANCEMENT

Abstract. The article describesthe procedures of information encryption and permutations, which would be used during development of information concealing (closure and concealing) system. Process of permutation is based on output sequences of shortest paths of graph algorithms of Bellman-Ford and Floyd Warshall. Creation of this system of information concealing and it's program implementation is aim of master degree project.

Key words: cryptography, permutation, Floyd Warshall algorithm, Bellman-Ford algorithm, cryptographic endurance.

Introduction.Proposed technology is concluded in that graph algorithms for finding shortest path Floyd Warshall, Bellman-Ford used only for finding shortest paths between two vertexes in graph.Combinationofcryptographyandoutputsequenceofshortestpathprovidessecrecyof information. Ifencryptedinformation (ciphertext) writtenin EC Bencryptionmodethanbyanalyzingtens of thousandsciphertexts it is possible to issue adecision that for example as encryption algorithm was used theparticularcryptographic cipher.SuchvulnerabilitieswerefoundinsymmetricalgorithmsDES, FEAL-N, in case if therewere used a pair weak key and weak plaintext was contained many repeated bytes which finally led to the situation that ciphertext contained many repeated bytes or not fully whitened at all. Thiswouldallowto3rdnonauthorizedpartymakean assumption of plaintext content character.In connection with that a technology was developed which allows on thebasis of thebuilt graph in representation of adjacency matrix to find shortest paths with usage of Floyd-Warshall, Bellman-Ford algorithms.Usageofadditionalpermutationofshortestpaths output sequences of Floyd-Warshall, Bellman Ford algorithms allows to protectciphertexts from differential cryptanalysis.This is explained by that after permutation ciphertext would be significantly differ from plaintext and even by using decryption key it would be not possible to obtain theoriginal plaintext.

Symmetrical block cipher encryption algorithmTwofish with key dependable substitution S-blocks. Symmetric block cipher Twofish with key dependable substitution S-blocks are of the most complicated for program implementation and most cryptographic endurable cipher in view of usage of Galois Fields ($GF\ 2^8$) [1,2]. Twofish was created by Bruce Schneier in 1998 year and following cipher had all set of technologies which science of cryptography reached specifically: Feistel Network, usage of irreducible polynomials of 8th degree in Galois Fields, unary operations: XOR, ROL, ROR, addition by modulus 32 (providing one-sidedness, concluding in complexity of retrieval square root by modulus, and also high speed on computer), entrance and output whitening, key dependable S-blocks, Hadamar cryptographic transform.

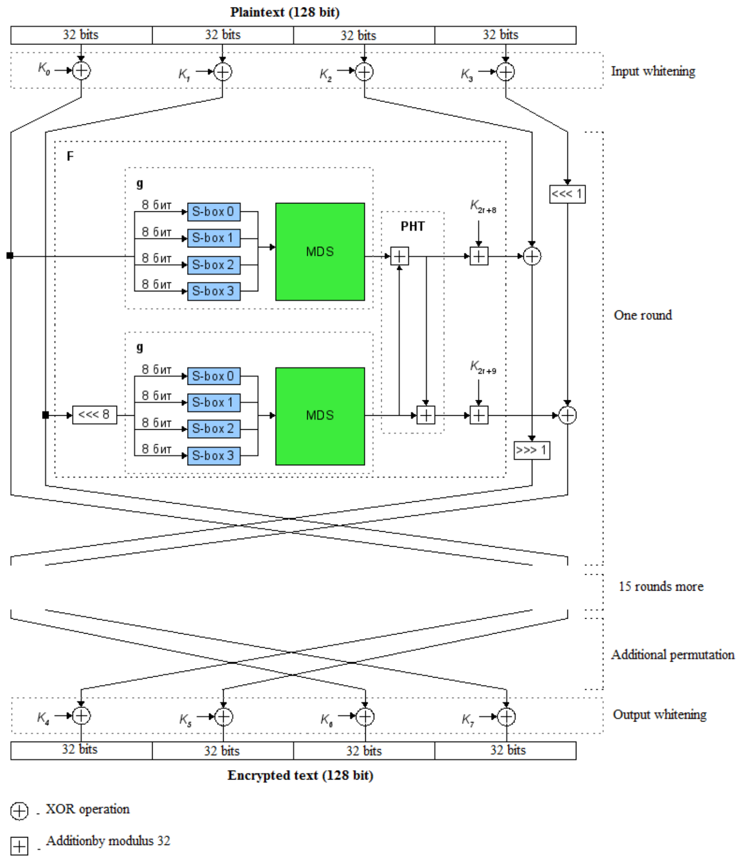

Figure 1 - Scheme of Twofish-128 algorithm

Describing the process of forming round keys:

M-encryption key, N-length of key in bits. Encryptionkey$M$breaking on8 $*$ $k$bytes$m_{0,\ldots\ldots\ldots,}m_{8k-1}$, $k = N/64$

Thenfollowing8 $*$ $k$bytesbreaksupon 32 bitswords (DWORD) (for4 bytes), it should be taken into account that in each words bytes are written in reverse order. Finally it is 2 $*$ k 32 bits wordsM_i

$$M_i = \sum_{j=0}^{3} m_{(4i+j)*2^{8j}} {}_{i=0,\ldots,2k-1}$$

Following2 $*$ k 32 bitswordsdividing on two vectors$M_e$and$M_o$of size in$k$ 32 bits word each

$$M_e = (M_0, M_2, \ldots, M_{2k-2})$$

$$M_o = (M_1, M_3, \ldots, M_{2k-1})$$

Finalroundsubkeysfor 16 rounds calculating by following rule, where$i$equals toround key of i round:

$$\rho = 2^{24} + 2^{16} + 2^{8} + 2^{0}$$

$$A_i = h(2ip, M_e)$$

$$B_i = ROL(h((2i+1)\rho, M_0), 8)$$

$$K_{2i} = (A_i + B_i) \ mod \ 2^{32}$$

$$K_{2i+1} = ROL((A_i + 2B_i) \ mod \ 2^{32}, 9)$$

Functionhfor encryption rounds and generation of key dependableS-blocks

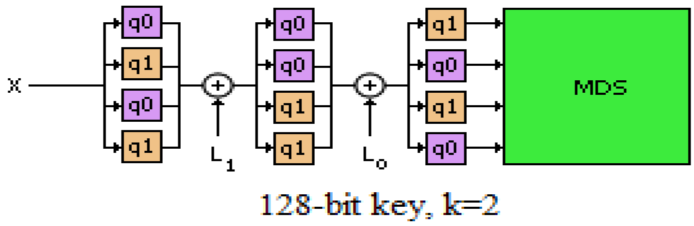

Figure 2 - Function h of Twofish-128 algorithm

$$\begin{matrix} 01 & EF & 5B & 5B \\ 5B & EF & EF & 01 \\ EF & 5B & 01 & EF \\ EF & 01 & EF & 5B \end{matrix}$$

Figure 3 - MDS matrix

MultiplicationinMDSmatrixproceeds byirreducible polynomial of 8th degree$x^8 + x^6 + x^5 + x^3 + 1$
q_0, q_1– fixed permutation blocks of 8 bits of incoming byte x.

Bytexsubstitutesontwopartsby 4 bitsineachpart (a_0, b_0), on following values$a_0, b_0$are heldnext calculations:

$$a_0 = x/16b_0 = xmod \ 16$$

$a_1 = a_0 \oplus b_0 b_1$=$a_0 \oplus ROR_4 = (b_0, 1) \oplus 8a_0 mod \ 16$
$a_2 = t_0[a_1]b_2 = t_1[b_1]$
$a_3 = a_2 \oplus b_2 b_3$=$a_2 \oplus ROR_4 = (b_2, 1) \oplus 8a_2 mod \ 16$

$$a_4 = t_2[a_3]b_4 = t_3[b_3]$$

$y \quad = 16b_4 + a_4$

Below presented fixed values if tables$t_0 \ldots t_3$, forq_0, q_1

Tables for q_0:

t_0=[8 1 7 D 6 F 3 2 0 B 5 9 ECA 4]
t_1=[E C B 8 1 2 3 5 F 4 A 6 7 0 9 D]
t_2=[B A 5 E 6 D 9 0 C 8 F 3 2 4 7 1]
t_3=[D 7 F 4 1 2 6 E 9 B 3 0 8 5 CA]

Tables for q_1:

t_0=[2 8 B D F 7 6 E 3 1 9 4 0 A C 5]
t_1=[1 E 2 B 4 C 3 7 6 D A 5 F 9 0 8]
t_2=[4 C 7 5 1 6 9 A 0 E D 8 2 B 3 F]
t_3=[B 9 5 1 C 3 D E 6 4 7 F 2 0 8 A]

Function G:

Function$g$calculated via function$h$: $g(X) = h(X, S)$

$$
\begin{matrix}
01 & A4 & 55 & 87 & 5A & 58 & DB & 9E \\
A4 & 56 & 82 & F3 & 1E & C6 & 68 & E5 \\
02 & A1 & FC & C1 & 47 & AE & 3D & 19 \\
A4 & 55 & 87 & 5A & 58 & DB & 9E & 03
\end{matrix}
$$

Figure 4 - RS Matrix

MultiplicationinRSmatrixconducted by irreducible polynomial of 8th degree$x^8 + x^6 + x^3 + x^2 + 1$

Bellman-Ford algorithm for finding the shortest path. The algorithm for finding the shortest paths of Bellman-Ford is based on the operation of edge relaxation. Initially, the algorithm is not applicable to graphs having a negative cycle, since it is possible to improve the distances for two vertexes in such graph indefinitely.Describing the pseudo-code procedure for finding the shortest path in the graph by the Bellman-Ford algorithm:

Table 1 - Pseudocode of Bellman-Ford algorithm

```
FunctionBellmanFord{
//Setting initial distances to all vertexes V equals to infinity, also for all ancestors of each vertexes setting zero value
For(inti=1;i<=V;i+=1){
d[i]=inf;
p[i]=0;}
d[s]=0; //Setting the initial value of 0 from source

//Traversing of all vertexes
For(inti=1;i<=V-1;i+=1){
//For each outgoing edge from vertex checking
For each Edge e in Edges(G){
//if thedistance between two vertexes a,balong certain edge c is less than current. This means that we are using edge c already having thecurrent edge of theshortest path between a,b + a certain edge c,than path could be improved.

If(distance[e.from]+lengthof(e)< distance[e.to]){
distance[e.to]=distance[e.from]+lengthof(e);
p[e.to]=e.from; //Writing to array of ancestors newly found vertex
}}}}
```

Floyd-Warshall algorithm for finding the shortest path. Floyd Warshall's algorithm also solves the problem of finding the shortest path between two vertexes in a graph. The algorithm concludes in taking vertex andit's outgoing edges one at a time and look through along which edges it is possible to improve the distance, this will be the intermediate edges.

Table 2 - Pseudocode of Floyd-Warshall algorithm

```
FunctionFloyd-Warshall{
d[uv]=w//Initial weights of graph edges are setting
For(inti=1;i<V;i+=1){ //Traversing of all graph vertexes
For(intu=1;u<V;u+=1){//Traversing of all graph edges
For(int v=1;v<V;v+=1){
d[uv]=min(d[uv-1],d[ui-1]+d[iv-1])//If distance could be improved by addition of intermediate vertex (edge) than writing following vertex(edge)
}}}}
```

Results of implementation in programming environment Microsoft Visual Studio 2013 on high level programming language C#

Demonstration of programming implementation of Twofish

Key-0X9F589F5C, 0XF6122C32, 0XB6BFEC2F, 0X2AE8C35A
Plaintext-0X16DB91D4, 0X9EC3B1E7, 0X6B08CB86, 0X19549F78

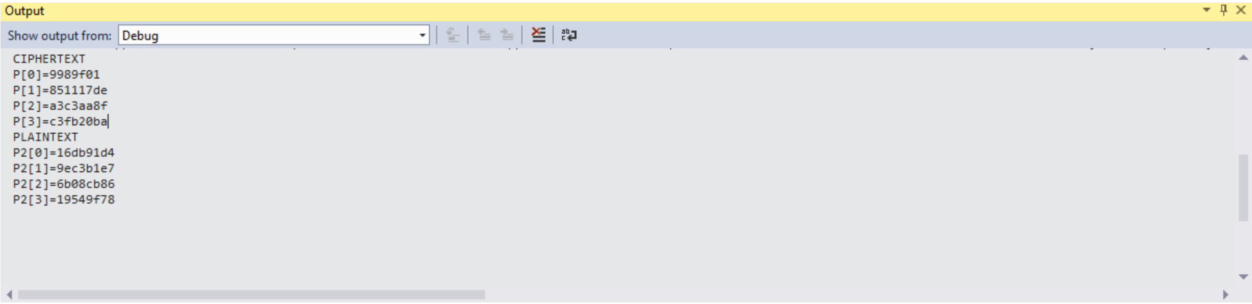

Figure 5 - Program implementation of Twofish

Demonstration of programming implementation of Floyd Warshall algorithm

Table 3 - Presented graph with 6 vertexes for Floyd Warshall and Bellman Ford algorithms

{0,10,18,8,inf,inf}, {10,0,16,9,21,inf}, {inf,16,0,inf,inf,15}, {7,9,inf,0,inf,12}, {inf,inf,inf,inf,0,23}, {inf,inf,15,inf,23,0}

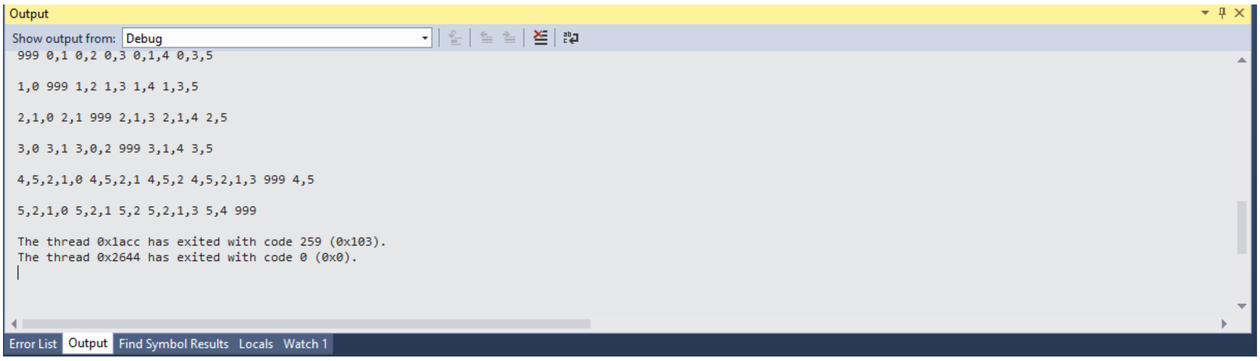

Figure 6 - Program implementation of Floyd Warshallalgorithm (shortest paths)

Demonstration of programming implementation of Bellman-Ford algorithm

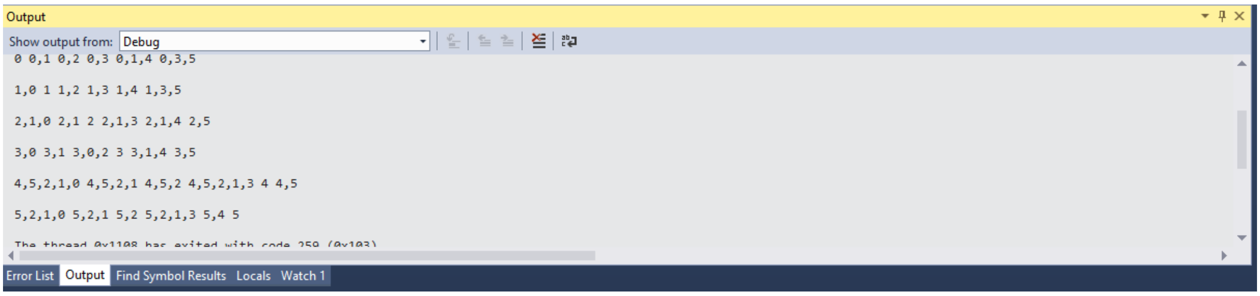

Figure 7 - Program implementation of Bellman-Ford algorithm (shortest paths)

Symmetric block encryption algorithm DES. The official standard of encryption FIPS 46-3 of 1977 [3]. As many ciphers of that period DES were based on substitution tables, fixes S-blocks and in own structure did not contained complicated cryptographical functions as subsequent ciphers based on Feistel network: IDEA, FEAL-N.Vulnerable side of DES appeared the presence of weak S blocks (nonuniform repetition of values inside each S blocks) which allowed to compute fast the key through differential cryptanalysis. Also with the growing of computational power of computers size of thekey in 64 bits was vulnerable side of cipher, allowing by the full selection attack to pick up the key. In additionby not using any complicated cryptographical functions, DES was not fully encrypted plaintexts.

Symmetric block encryption algorithm 3DES.

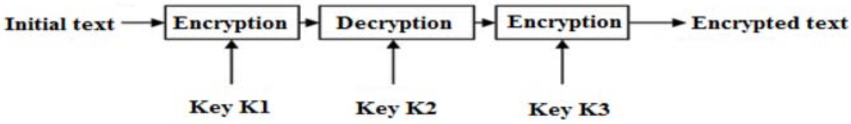

Figure 8 - Scheme of 3DES algorithm

3DES is completely analogous to DES, but 3 keys of 64 bits are used [4]. The total length of 192 bits, this solved the problem of attacks based on full selection, but the problem with pairs of a weak key, weak plain text was not solved, which served as a complete abandonment of this cipher and in the development process, paying more attention to complex cryptographic functions, and not just processes of permutations and replacements [5].

Conclusion. Developed systems allowto use output sequences of Floyd Warshall and Bellman-Ford algorithms for theapplianceof additional permutation of ciphertext of any cipher. Output sequences of shortest paths do not know to 3rdnonauthorizedside which allows to achieve full secrecy during message exchange. Further work is planned on secure transmission and generations of graphs between 2 subscribers of thesecured channel.

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ИСПОЛЬЗОВАНИЕ АЛГОРИТМОВ ФЛОЙДАУОРШЕЛЛА, БЕЛЛМАНА-ФОРДА ДЛЯ ДОБАВЛЕНИЯ ПЕРЕСТАНОВОК ШУМА БЛОЧНЫХ ШИФРОВ ДЛЯ УСИЛЕНИЯ КРИПТОСТОЙКОСТИ

Аннотация. В статье описаны процедуры шифрования информации и перестановок, которые будут использованы при разработке системы скрытия (закрытия и скрытия) информации. Процесс перестановки основан на выходной последовательности кратчайших путей алгоритмов на графах Беллмана-Форда и Флойда Уоршелла. Создание этой системы скрытия информации и её программная реализация является целью магистерской диссертации.

Ключевые слова: криптография, перестановка, алгоритм ФлойдаУоршелла, алгоритм Беллмана-Форда, криптостойкость.

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ҚАУІПСІЗ СТЕГАНОГРАФИЯ ҚҰРЫЛЫМЫ ДИНИЦ ЕҢ ҮЛКЕН АҒЫН АЛГОРИТМІНЕ ҮШІН НЕГІЗДЕЛГЕН

Аннотация. Мақалада ақпараттарды жасыру (жабу және жасыру) жүйесін жасау үшін қолданылатын ақпаратты және өтпелерді шифрлау процедуралары сипатталады. Алмасу процесі ең қысқа жолдардың графтар алгоритмдер Беллман-Форд және Флойд Уоршелл шығу тізбегіне негізделген. Бұл ақпаратты жасыру жүйені құру және оның бағдарламалық қамтамасыз етуді енгізу магистрлік диссертация мақсаты.

Түйін сөздер: криптография, аустыру, Флойд Уоршелл алгоритм, Беллман-Форд алгоритм, криптографиялық күші.

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INTEGRO-DIFFERENTIAL EQUATIONS WITH REGULAR KERNELS

Abstract. At the research of harmonious waves in deformable bodies, the concept of phase speed as the speed of environment condition change is implemented; at the same time, the phase speed is expressed through the frequencies of own fluctuations and therefore the research of harmonious waves distribution has a direct bearing on the problems of definition of own forms and frequencies of the fluctuations limited in terms of plates. More difficult fluctuation of rectangular flat element is the fluctuation when two of the opposite edges are hinge-supported, and two other edges have different types of fixing or they are free from tension. This class of tasks leads to the transcendental equations for determination of frequencies of own fluctuations which can be solved both numerically and analytically. The transcendental frequency equations can be reduced to algebraic ones and to investigate the influence of both boundary conditions at the edges of rectangular plate or rectangular flat element and parameters of geometrical and mechanical character on the frequencies of own fluctuations of rectangular flat elements. In the study of oscillations and wave processes in a deformable solid body core of a viscoelastic operators it is advisable to take regular, so as soon as such statements describe the instantaneous elasticity, and then viscous flow, which is typical for deformable bodies. Integro-differential equations with regular kernels, as you know, the equivalent differential equations.

Key words: Maxwell model, core, regulator, plates, finite number, own fluctuations, compelled fluctuations, transcendental, equations.

We will consider flat element as isotropic uniform elastic plate of constant thickness.

We will be limited to the task solution based on approximate equation of quartic cross fluctuations

$$A_0 \frac{\partial^4 W}{\partial t^4} - A_1 \Delta \frac{\partial^2 W}{\partial t^2} + A_2 \Delta^2 W + \frac{\partial^2 W}{\partial t^2} = \Phi(f_z, f_{jz}) \left(j = x, y \right) \tag{1}$$

wherecoefficients A_j are equal to

$$A_0 = \frac{h^2(7-8\nu)}{12b^2(1-\nu)};\ A_1 = \frac{2h^2(2-\nu)}{3(1-\nu)};\ A_2 = \frac{2h^2b^2}{3(1-\nu)} \tag{2}$$

ν – Poisson ratio; b – speed of cross waves distribution in plate material.

If the material of the plate satisfies the Maxwell model, that is, the operators L, M are equal

$$(L,M)(\xi) = (\lambda,\mu)\left[\xi(t) - \frac{1}{\tau}\int_0^t e^{-\frac{t-\xi}{\tau}} \xi(\xi)d\xi\right] \tag{3}$$

where τ - only one time of relaxation, then

$$A_0\left(\frac{\partial^4 W}{\partial t^4}+\frac{2}{\tau}\frac{\partial^3 W}{\partial t^3}+\frac{1}{\tau^2}\frac{\partial^2 W}{\partial t^2}\right)-A_1\Delta\left(\frac{\partial^2 W}{\partial t^2}+\frac{1}{\tau}\frac{\partial W}{\partial t}\right)+A_2\Delta^2 W+$$

$$+\left(\frac{\partial^2 W}{\partial t^2}+\frac{1}{\tau}\frac{\partial W}{\partial t}\right)=\Phi_1(f_{z,}f_{jz});\ (4)$$

As seen, the kernel (3) is regular and in the place of equation (1) we have equation (4). Equation (4.) can be generalized for any regular kernel, containing a finite number of regular components.

For other approximate oscillation equations for a plane element these equations for regular kernels can also be reduced to partial differential equations.

As plate edges $(y=0;l_2)$ As plate edges are hinge-supported, the solution of the equation (1) we will find in

$$W(x,y,t)=\exp\left(i\frac{b}{h}\xi t\right)\sum_{k=1}^{\infty}W_k(x)\sin\left(\frac{k\pi y}{l_2}\right) \tag{5}$$

Substituting (5) in the equation (1), for W_k we get ordinary differential equation

$$\frac{d^4W_k}{dx^4}+B_0\frac{d^2W_k}{dx^2}+B_1W_k=0 \tag{6}$$

where coefficients B_0, B_1 are equal to

$$B_0=\left[\frac{A_1}{A_2}\xi^2\left(\frac{b}{h}\right)^2-2\left(\frac{k\pi}{l_2}\right)^2\right];$$

$$B_1=\left[\left(\frac{k\pi}{l_2}\right)^4+\frac{A_0}{A_2}\xi^4\left(\frac{b}{h}\right)^4-\frac{A_1}{A_2}\xi^2\left(\frac{b}{h}\right)^2\left(\frac{k\pi}{l_2}\right)^2-\frac{1}{A_2}\left(\frac{b}{h}\right)^2\xi^2\right] \tag{7}$$

We will write down the common solution of the equation (6) as

$$\begin{aligned}W_k(x)=&C_1\left[\frac{\cos(a_0x)}{a_0^n}+\frac{\cos(a_1x)}{a_1^n}\right]+C_2\left[\frac{\cos(a_0x)}{a_0^n}+\frac{\cos(a_1x)}{a_1^n}\right]+\\&+C_3\left[\frac{\sin(a_0x)}{a_0^m}+\frac{\sin(a_1x)}{a_1^m}\right]+C_4\left[\frac{\sin(a_0x)}{a_0^m}+\frac{\sin(a_1x)}{a_1^m}\right],\end{aligned} \tag{8}$$

where C_j - integration constants, a_i, a_j - roots of the characteristic equation

$$a^4+B_0a^2+B_1=0 \tag{9}$$

andare equal to

$$a_{0,1} = \sqrt{\frac{B_0}{2} \pm \sqrt{\left(\frac{B_0}{2}\right)^2 - B_1}} \tag{10}$$

Integers (n,m) are got out of solution simplification condition at the satisfaction of boundary condition at the left edge $x=0$, and other boundary conditions at $x=l_1$ lead to the transcendental equation for the determination of frequencies of the plate own fluctuations.

We will analyse transcendental frequency equations of the first point.

In the beginning we will consider the simplest transcendental equation

$$\alpha_0 \cos(\alpha_0 l_1)\sin(\alpha_1 l_1) - \alpha_1 \sin(\alpha_0 l_1)\cos(\alpha_1 l_1) = 0. \tag{11}$$

Wewillimplementdesignations

$$l = \frac{l_1}{h};\ \alpha^1_{0.1} = \sqrt{\frac{B^1_0}{2} \pm \sqrt{\left(\frac{B^1_0}{2}\right)^2 - B^1_1}}; \tag{12}$$

$$B_0^{"} = \left[(2-\nu)\xi^2 - 2\gamma\right];\ \gamma = \left(\frac{\pi kh}{l_2}\right)^2;$$

$$B_1^{;} = \left[\gamma^2 + \frac{7-8\nu}{8}\xi^4 - (2-\nu)\gamma\xi^2 - \frac{3}{2}(1-\nu)\xi^2\right]$$

and further we will lower strokes for simplicity.

As sines and cosines from any argument are equal

$$\sin z = \sum_{i=0}^{\infty}(-1)^i \frac{z^{2i+1}}{(2i+1)!};\ \cos z = \sum_{j=0}^{\infty}(-1)^j \frac{z^{2j}}{(2j)!};$$

the equation (11) is equivalent to the following

$$\alpha_0\alpha_1 \sum_{i=0}^{\infty}\sum_{j=0}^{\infty}(-1)^{i+j}\frac{\alpha_1^{2i}\alpha_0^{2j} - \alpha_0^{2i}\alpha_1^{2j}}{(2i+1)!(2j)!} l^{2(i+j)} = 0 \tag{13}$$

If to accept that size is determined from the formula (10) with plus sign under the root, then it follows that this root does not turn zero at any values y, ν, ξ.

Therefore, in the beginning it is possible to put $a_1 = 0$ or for ξ we get the equation

$$\xi^4 - \frac{8\left[(2-\nu)\gamma + \frac{3}{2}(1-\nu)\right]}{(7-8\nu)}\xi^2 + \frac{8\gamma^2}{(7-8\nu)} = 0; \tag{14}$$

which roots are equal to

$$\xi_{1,2} = (7-8\nu)^{-\frac{2}{2}} \sqrt{4\left[(2-\nu)\gamma + \frac{3}{2}(1-\nu)\right] \pm} \tag{15}$$
$$\pm \sqrt{8(1+\nu^2)\gamma^2 + 3\gamma(1-\nu)(2-\nu) + \frac{9}{4}(1-\nu)^2}$$

as the ranks in the formulae of trigonometrical functions meeting ranks in the equation (13), equivalent to the equation (11) also meeting, at the research of private equation (13) it is possible to be limited to the final number of the first composed.

Having taken first three composed in the ranks (13), we will write down it as

$$\alpha_0\alpha_1(\alpha_1^2-\alpha_0^2)\left\{\frac{1}{3}l^2 - \frac{1}{30}(\alpha_1^2+\alpha_0^2)l^4 + \right\}\times \tag{16}$$
$$\times\left[\frac{1}{840}(\alpha_1^4+\alpha_0^2\alpha_1^2+\alpha_0^4)+\frac{1}{360}\alpha_0^2\alpha_1^2\right]l^6 + \dots \Big\} = 0$$

Roots from the formula $\alpha_1 = 0$ are equal (15). The value $(a_1^2 - a_0^2)$ is other than zero at any y, ν, ξ.

If in formula (16) to take only two first terms, then we get

$$(\alpha_1^2+\alpha_0^2) - 10l^{-2} = 0$$

or

$$B_0 - 10l^{-2} = 0 \quad (17)$$

andfrequency equation

$$\xi^2 = \frac{2\gamma + 10l^{-2}}{(2-\nu)}; \tag{18}$$

which positive root is equal to

$$\xi = \sqrt{\frac{2\gamma+10l^{-2}}{(2-\nu)}} \tag{19}$$

If in formula to take all three first terms, then we will get

$$\left[(\alpha_1^4+\alpha_0^4)+\frac{10}{3}\alpha_0^2\alpha_1^2\right] - 28(\alpha_1^2+\alpha_0^2)l^{-2} + 280l^{-4} = 0 \tag{20}$$

or

$$\left[B_0^2 + \frac{4}{3}B_1\right] - 28B_0l^{-2} + 280l^{-4} = 0$$

and the frequency equation corresponding to them

$$\left[(2-\nu)^2+\frac{7+8\nu}{6}\right]\xi^4-\left[(2-\nu)\left(\frac{16}{3}\gamma+28l^{-2}\right)+2(1-\nu)\right]\xi^2+$$

$$+\left[\frac{16}{3}\gamma^2+56\gamma l^{-2}+280l^{-4}\right]=0, \qquad (21)$$

which has two positive roots.

It is similarly possible to take first four and more слагаемых in the formula (13) and to get more exact frequency equation and corresponding frequencies ξ.

To find the frequency equation from ranks of the equation (13) it is necessary to find out condition of deduction legitimacy of finite number of terms in the ranks (13).

We will apply Dalamber's principle of ranks convergence to the ranks in the equation (13). We will get

$$\left|\frac{\alpha_0^2\alpha_1^2 l^2}{(2i+3)(2j+2)}\right|\le q^2<1 \qquad (22)$$

where $0<q<1$.

It follows from the inequality (22) that

$$\left|a_0^2 a_1^2\right|\le q_{i,j}^2=q_{i,j}^2=q^2\,\frac{(2i+3)(2j+2)}{l^2} \qquad (23)$$

The analysis of inequality (23) shows that it is correct when performing inequality

$$-\left(\frac{8}{7-8v}\right)q_{i,j}^2\le\xi^4-2D\xi^2+E\le\left(\frac{8}{7-8v}\right)q_{i.j}^2=C_{i,j}^2$$

wherecoefficients D,E are equal to

$$D=\frac{4\left[(2-\nu)\gamma+\frac{3}{2}(1-\nu)\right]}{(7-8v)};\ E=\frac{8\gamma^2}{(7-8v)}$$

orinequalities

$$D^2-E\le C_{i,j}^2 \qquad (24)$$

At the set parameters of geometrical and mechanical character from the inequality (24) it is possible to define necessary number of the first terms in ranks (13) to find the frequency equation relative frequencies ξ.

We will consider transcendental equation frequency equation

$$2-\frac{a_0^2+a_1^2}{a_0 a_1}\sin(a_0 l_1)\sin(a_1 l_1)-2\cos(a_0 l_1)\cos(a_1 l_1)=0 \qquad (25)$$

As well as transcendental equation (11), the equation (25) is equivalent to the following

$$a_0 a_1\left\{2\left[1-\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}(-1)^{i+j}\frac{a_0^{2i}a_1^{2j}}{(2i)!(2j)!}J^{2(i+j)}\right]-\right. \qquad (26)$$

$$\left.-(a_0^2+a_1^2)\sum_{i=0}^{\infty}\sum_{jj=0}^{\infty}(-1)^{i+j}\frac{a_0^{2i}a_1^{2j}}{(2i+1)!(2j+1)!}J^{2(i+j+1)}\right\}=0$$

It follows from the equation, that, first, $a_1=0$ also we got frequencies (15).
We will write down the equation (26), having written out the first terms

$$\left\{(a_0^2+a_1^2)J^2-\frac{1}{6}(5a_0^4+5a_1^4+a_0^2a_1^2)J^4+\right\}\times$$
$$\times\frac{1}{90}\left[a_0^6+a_1^6+7a_0^2a_1^2(a_0^2a_1^2)\right]J^6+\ldots\ \}=0 \qquad (27)$$

From (27) it also follows that it can be supposed $(a_0^2+a_1^2)=0$ and we will get

$$B_0=0 \text{ or } \xi^2-\frac{2\gamma}{(2-\nu)}=0 \qquad (28)$$

which root is equal to

$$\xi=\sqrt{\frac{2\gamma}{(2-\nu)}} \quad (29)$$

Similarly, we can put approximately

$$(a_0^2+a_1^2)-\frac{J^2}{6}(5a_0^4+5a_1^4+a_0^2a_1^2)=0 \quad (30)$$

and we will get frequency equation

$$(5B_0^2-9B_1)-\frac{6}{J^2}B_0=0 \qquad (31)$$

having positive roots.
We will consider more difficult transcendental equation

$$4\left[Q\left(Q-a_0^2-a_1^2\right)+a_0^2a_1^2\right]\left[1-\cos\left(a_0l_1\right)-\cos\left(a_1l_1\right)\right]+$$
$$+2\left[\frac{a_0^3}{a_1^3}\left(Q-a_1^2\right)^2+\frac{a_1^3}{a_0^3}\left(Q-a_0^2\right)^2\right]\sin\left(a_0l_1\right)-\sin\left(a_1l_1\right)=0, \tag{32}$$

where

$$Q=\frac{3-2v}{7-4v}\left[\frac{\xi^2}{h^2}-2\left(\frac{\pi k}{l_2}\right)^2\right]$$

which is equivalent to the following

$$2\left[Q_0(Q_0-a_0^2-a_1^2)+a_0^2a_1^2\right]\left[1-\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}(-1)^{i+j}\frac{a_0^{2i}a_1^{2j}}{(2i)!(2j)!}J^{2(i+j)}\right]+$$

$$+\left[a_0^4(Q_0-a_1^2)^2+a_1^4(Q_0-a_0^2)^2\right]\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}(-1)^{i+j}\frac{a_0^{2i}a_1^{2j}}{(2i+1)!(2j+1)!}J^{2(i+j+1)}=0 \tag{33}$$

$$Q_0=\left(\frac{3-2v}{7-4v}\right)(\xi^2-2\gamma).$$

We will write out the first terms in the equation (33)

$$\left[\left(a_0^2+a_1^2\right)L_1+L_2\right]J^2-\left[L_1\left(\frac{a_0^4+a_1^4}{12}+\frac{a_0^2a_1^2}{2}\right)+L_2\left(\frac{a_0^2+a_1^2}{6}\right)\right]J^4+$$
$$+\left\{\frac{1}{360}L_1\left[a_0^6+a_1^6+15a_0^2a_1^2\left(a_0^2+a_1^2\right)\right]\right\}+ \tag{35}$$
$$+\frac{1}{20}L_2\left(a_0^4+a_1^4+\frac{10}{3}a_0^2a_1^2\right)J^6+\ldots=0;$$

$$L_1=\left[Q_0\left(Q_0-a_0^2-a_1^2\right)+a_0^2a_1^2\right];$$

$$L_2=\left[a_0^4\left(Q_0-a_1^2\right)^2+a_1^4\left(Q_0-a_0^2\right)^2\right].$$

Being limited by the first term in the formula (33), we will get

$$\left(a_0^2+a_1^2\right)L_1+L_2=0 \tag{37}$$

or

$$Q_0^2\left(B_0^2-2B_1\right)-2Q_0B_0B_1+2B_1^2+B_0\left[Q_0\left(Q_0-B_0\right)+B_1\right]=0 \tag{39}$$

The frequency equation (36) is the algebraic equation relatively to ξ and already depends on the parameter γ.

Equations of higher orderrelativelyto ξ already depend on the parameter γ .

It is also possible to consider other boundary value problems.

Thus, transcendental frequency equations can be reduced to algebraic and to investigate influence of both boundary conditions at the edges of rectangular plate or rectangular flat element, and parameters of geometrical and mechanical character on frequencies of own fluctuations of rectangular flat elements.

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ТҰРАҚТЫ ЯДРОЛЫ ИНТЕГРО-ДИФФЕРЕНЦИАЛДЫҚ ТЕҢДЕУЛЕР

Аннотация. Берілген жұмыста пластинкадан құралған материалдың қатпарлылығын, реологиялық тұтқыр қасиеттерін , анизотропиясын және т. б. зерттеу нәтижелері есере отырып шешілген меншікті және еріксіз тербелістер есебіні қарастырылған. Зерттеу натижесңінде гармоникалық толқындардың деформация-ланатын денелер жағдайындағы фазалық жылдамдығын, орта күйінің өзгеру жылдамдығы деп қарастырады, бұл ретте фазалық жылдамдық жиілігі меншікті тербеліс арқылы өрнектеледі, сондықтан гармоникалық толқындардың таралу процессін зерттеу проблемаларын анықтау, меншікті нысандар мен берілген прпластинкалардың жиілік шектелген тербелісіне тікелей қатысты болады. Екі қарама-қарсы шеттері топсалап бекітілген, ал басқа екі жағы әр түрлі бекіту түрлерімен ұстатылған немесе кернеу әсер етпейтіндей болып орналасқан болса, онда бұл жағдай аса күрделі тікбұрышты жазық элемент тербелісі болып табылады, Мұндай есептер классы сандық түрде де немесе аналитикалық түрде де шешілетін меншікті жиілік тербелісін анықтайтын трансценденттік теңдеулерге акеледі. Трансценденттік жиіліктік теңдеуін алгебралық түрге келтіре отырып, тік бұрышты пластинкалар шектік шарттарын, геометриялық және механикалық сипаттағы тік бұрышты жазық элементтің тербеліс теңдеуініңі әсері негізінде зерттеуге болады.

Тірек сөздер: Максвел моделі, ядро, регулятор, пластинки, конечное число, собственные колебания, трансцендентные, уравнения, реология.

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ИНТЕГРО-ДИФФЕРЕНЦИАЛЬНЫЕ УРАВНЕНИЯ С РЕГУЛЯРНЫМИ ЯДРАМИ

Аннотация При исследовании колебания и волновых процессов в твердом деформируемом теле ядро вязкоупругих операторов целесообразно брать регулярными, так как только такие операторы описывают мгновенную упругость, а затем вязкое течение, что характерно для деформируемых твердых тел. Интегро-дифференциальные уравнения с регулярными ядрами, как известно, эквивалентны дифференциальным уравнениям в частных производных. При исследовании гармонических волн в деформируемых телах вводится понятие фазовой скорости как скорости изменения состояния среды, при этом фазовая скорость выражается через частоты собственных колебаний и поэтому исследование распространения гармонических волн имеет прямое отношение к проблемам определения собственных форм и частот колебаний ограниченных в плане пластин. Более сложным колебанием прямоугольного плоского элемента является колебание, когда два из противоположных краёв шарнирно опёрты, а два других края – имеют различные виды закрепления или свободны от напряжений. Данный класс задач приводит к трансцендентным уравнениям для определения частот собственных колебаний, которые можно решать как численно, так и аналитически. Трансцендентные частотные уравнения можно сводить к алгебраическим и исследовать влияние, как граничных условий по краям прямоугольной пластинки или прямоугольного плоского элемента, так и параметров геометрического и механического характера на частоты собственных колебаний прямоугольных плоских элементов.

Ключевые слова: модели Максвелла, ядро, реттеуіш, пластинккалар, ақырғы сан, дербес тербеліс, трансцендентік, теңдеу, реология.

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MANAGING THE MYSQL DATABASE AND THE STAGES OF DEVELOPMENT OF CLIENT SERVER INFORMATION SYSTEM USING MYSQL

Abstract. The paper covers various aspects and tasks of MySQL database administration, main duties and methodological instructions, principal questions and responsibilities. MySQL management software can be used by any user. The article also presents the methods of modification and usage. It also presents the internal features and abilities, work platforms and database copying, the ability to backup deleted data, the stages of data processing using the client-server technology. The database provides excellent technical features. MySQL is a client-server system, including a multithreaded SQL server, supporting a big number of various computers, programs and libraries, administration tools and offering an advanced API. Data types and methods of table creation are given. MySQL provides an easy-to-use installation procedure. MySQL makes it easy to share data between users.

Key words: MySQL,database administrator, development of IS on client server technology, databases, database types.

The main components of MySQL DBMS are covered. As is well known, MySQL is a relational database management system. In a relational database system, the data is stored in multiple separate tables. That is why, this paper discusses methods of working with tables that can facilitate work in MySQL. The questions concerning SQL queries are considered as well.

MySQL. MySQL DBMS consists of several main components. Knowledge of their essence and designation allows to better understand the nature of the managed system and principles of the work of its various tools. It is strongly recommended to spend a little time to better understand the material given further in the text. It will largely ease the work. In particular it is important to work over the following aspects of MySQL.

- MySQL server. The mysqld server performs all operations on databases and tables. To start the server, monitor its operation and restart in case of failure, the program safe_mysqld (daemon) is used.
- MySQL client programs and utilities. To interact with the server and perform a number of administrative tasks, various MySQL programs are used, the most important of which are the following:
- mysql. An interactive program that allows you to send SQL queries to the server and view the results of their execution.
- mysqladmin. An administrative tool that allows you to perform operations such as shutting down the server, creating and deleting databases. The same program can be used to check the status of the server, if something there is something wrong with its work.
  - isamchk or myisamchk. Utilities designed to analyze and optimize tables, and restore them in case of damage.
  - mysqldump. A tool for backing up databases or copying them to another server.
- SQL is a server-side language. You can perform some administrative tasks only with the mysqladmin command-line utility. Sometimes it is much more effective to complete a task if an administrator can "communicate" with the server in its native language. Suppose that you need to check why user privileges do not work as expected. Unfortunately, it is impossible to directly "talk" to the server in human language. But you can use the mysql client program and then send an SQL query to analyze the permission tables.

- MySQL, developed mostly in C / C ++, has been tested on many platforms, including Windows, Linux, FreeBSD, Mac OS X, OS / 2, Solaris, and others.
- MySQL provides the API (Application Programming Interface) for C, C ++, Eiffel, Java, Perl, PHP, Python, Ruby and Tcl. MySQL can be successfully used both for building Web pages using Perl, PHP and Java, and for creating a desktop application program using Delphi, Builder C ++ or the .NET platform.

The development of IS using client-server technology consists of several stages:

1. the server part of the DBMS is installed on the server in a computer network (for example, Microsoft SQL Server, MySQL, Oracle. If a web-interface is implemented, then a web server program is installed on the server too (for example, Apache);
2. If client applications are implemented, then the client part is installed on all client parts of the network (this step is not necessary and is performed only if users of the information system have the ability to manage the server)[7];
3. The server and the client parts of the DBMS and the web server are configured;
4. The data structure (links between tables and field types) is defined, primary and secondary tables are also defined in queries;
5. Tables and queries running on the server side are created. Before creating queries, the tables are filled with initial data. Stored procedures, user functions, diagrams, and triggers are also created;
6. In the case of using a client application, connectivity objects are created using the programming language, they are connected to tables, queries and stored procedures. Also, queries and stored procedures to be executed on the server side are created;
7. Forms are created;
8. Reports are created;
9. The system is filled up with real data.

The MySQL software is open source software.

Open source software means that anyone can use and modify it. Such software can be obtained over the Internet and used for free. In this case, each user can study the source code and change it according to his needs.

Technical capabilities of MySQL DBMS

MySQL is a client-server system that contains a multi-threaded SQL server that supports various database computers, as well as several different client programs and libraries, administrative tools, and a wide range of APIs.

Security

The security system is based on privileges and passwords with the ability to verify them from a remote computer, thereby providing flexibility and security. Passwords are crypted when they are sent over the network in the process of getting connected to the server. Clients can connect to MySQL using TCP / IP sockets, Unix sockets or named pipes (named pipes, under NT)

MySQL is very fast, reliable and easy to use. If you need namely these features, try working with this server. MySQL also has a number of convenient features, developed in close contact with users. Initially, the MySQL server was designed to manage large databases in order to provide faster performance compared to existing analogues at that time. And since then this server has been successfully used by enterprises with high requirements. Despite the fact that MySQL is constantly improving, it already provides a wide range of useful functions. Due to its availability, speed and security, MySQL is very suitable for accessing databases on the Internet.

It's only rarely that you need to view the whole output of the query at once (that is, all the records that satisfy the query expression). For example, we may need only to calculate how many records satisfy a particular condition, or to select only the first 10 records from the data. The mechanism of using sockets implies using client-server technology, which means that a special program must be running in the system-a MySQL server that accepts and processes requests from client programs. Since all work is actually done on the same machine, the overhead of working with network resources is insignificant (installation and maintenance of connection with MySQL server is quite cheap). MySQL has a three-level architecture: databases - tables - records. The MySQL databases and tables are physically represented by files with the frm, MYD, MYI MySQL is very fast, reliable and easy to use. If you need namely these features, try working with this server. MySQL also has a number of convenient features, developed in close contact with users. Initially, the MySQL server was designed to manage large databases in order to provide faster performance compared to existing analogues at that time. And since then this server has been successfully used by enterprises with high requirements. Despite the fact that MySQL is constantly improving, it already provides a wide range of useful functions. Due to its availability, speed and security, MySQL is very suitable for accessing databases on the Internet.

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Data types

Processing numeric data

MySQL provides five integrak types of data, each of which can be signed (by default) or unsigned (by adding the word UNSIGNED after the type name).

Type name	***bits***	***signed range***	***unsigned range***
TINYINT	8	-128..127	0..255
SMALLINT	16	-32768..32767	0..65535
MEDIUMINT	24	-8388608..8388607	0..16777215
INTEGER	32	-147483648..2147483647	0..4294967295
BIGINT	64	$-(2^{63})..(2^{63}-1)$	$0..(2^{64})$

The INT type is used as an alias for INTEGER. Other aliases are: INT1 = TINYINT, INT2 = SMALLINT, INT3 = MEDIUMINT, INT4 = INT, INT8 = BIGINT, and MIDDLEINT = MEDIUMINT.

Processing String Data

MySQL supports the following string types (M denotes the maximum displayed size or PRECISION).

CHAR (M) - a string of fixed length always complemented by spaces on the right. M can be in the range from 1 to 255 characters.

VARCHAR (M) is a string of variable length. Closing whitespace is deleted by the database when writing a value. M can be in the range from 1 to 255 characters.

ENUM ('value1', 'value2', ...) is an enumeration. A string object that can have only one value selected from the specified list (or NULL). The list can have up to 65,535 different values.

SET ('value1', 'value2', ..) is a set. A string object that can have multiple values (or none), each of which must be selected from the specified list. SET can have a maximum of 64 elements.

The length of the CHAR and VARCHAR types is limited to 255 bytes. All string types support binary characters, including NULL (for literal strings, use the $ dbh-> quote () method).

The following aliases are also supported:

BINARY (num) CHAR (num) BINARY

CHAR VARYING VARCHAR

LONG VARBINARY BLOB
LONG VARCHAR TEXT
VARBINARY (num) VARCHAR (num) BINARY

Basic Commands

You can view the list commands supported by mysql program by running it with the --help option:

shell>mysql --help

The list of commands displayed by this command is well documented and therefore is not given here.You can start the MySQL database as follows:

mysql [OPTIONS] database

Description of MySQL database

The client part of MySQL is called mysql. It provides a command-line interface for MySQL and a non-interactive batch processing capability.The options supported by mysql are shown in the table below. You can use either a "short" single character or a more detailed version.

Mysql options

option	**Description**
-\?, --help	Reference
option	**Description**
-d, --debug=[options]	*Output the debug information to the protocol In the following general form 'd: t: o, filename'*
-d, --debug-info	Output debugging information on exiting the program
-e, --exec	*Execute the command and exit, the implicit form of the --batch option*
-f, --force	Continue even if we encounter a SQL error
-h, --hostname=[hostname]	Specifies the name of the server you want to connect to
-P, --port=[port]	Port for connecting to MySQL server
-p, --password=[password]	The user's password for connecting to the MySQL server. Note that there should not be a space between -p and password
-q, --quick	Fast (non-bufferized) output, can slow down the server if the output is suspended
-s, --silent	Silent output
-u, --user=[user]	The user name for connecting to the MySQL server. It is optional, if the user name is the same as your login. By default, your login name is used as a user name, which simplifies configuration
Окончание табл. 1	
Опция	**Описание**
-v, --verbose	Detailed output. -v option can be doubled or tripled for more detailed output.
-w, --wait	If the connection fails, then wait and try again.
-B, --batch	Run in batch mode. No requests and errors shown in STDOUT. It is automatically set when reading from a record to a pipe (pipe). The results will be displayed in a tab-separated format. One line of the result corresponds to one line of output
-I, --help	Equivalent to ?
-V, --version	Print version information

In interactive mode, mysql will print results in a table similar to the example below. If no password or user name are provided, mysql will try to log in to the database server using your login and NULL (BLANK) password. If your mysql login is different from your login in unix, or if you have a password, the connection to MySQL will not be performed.For example:

bsd# mysql -u coobic
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 4 to server version: 4.0.12-max
Type 'help;' or '\h' for help.Type '\c' to clear the buffer.

Implementation of SQL in MySQL DBMS

Database creationTo see a listof databases currently existing on the server, you can use the SHOW command:

mysql> **SHOW DATABASES;**

```
+----------+
| Database |
+----------+
| mysql    |
| test     |
| trf      |
+----------+
```

3 rows in set (0.00 sec)

The mysql database is essential as it stores the user access rights. The test database is often used for experiments.However, you can not see all the databases, if you do not have the permission to run SHOW DATABASES.If the test database exists, try accessing it:

mysql>**USEtest**

Databasechanged

The USE command, like QUIT, does not need a semicolon (of course, you can also end the command with a semicolon). The USE command differs from others also by something else: it should be specified in one line.If the administrator creates a database for you and grants all permissions, you can start working with it right away. In the absence of a database, you will have to create it yourself:

mysql> **CREATE DATABASE perpetuum;**

Query OK, 1 row affected (0.00 sec)

In Unix, the case of database names (unlike in SQL keywords) matters, so in this OS you will always have to remember that perpetuum, and Perpetuum or something else are different names. The same rule applies to table names (in Windows this restriction does not work.However when accessing databases and tables within one query, you should follow only one particular case).When creating a database, it is not selected automatically; you must select it separately. Make perpetuum the current database using the following command:

mysql> **USE perpetuum**

Database changed

You need to create a database only once, but you must select it in each mysql session. You can do this using the USE command above. And also you can choose the database from the command line when running mysql. To do this, just enter its name after the connection parameters . For example:

shell>**mysql -h host -u user -p perpetuum**

Enter password: ********

Note: in the above command, perpetuum is not a password. Enter the password at the command line after the -p option without a space (for example, -pmypassword, not -p mypassword). However, it is still better not to specify the password in the command lined for security reasons.

Creating a table

Using the CREATE TABLE command, we define the structure of the new table:

mysql> **CREATE TABLE TABLE1 (**
-> **NUMBER INTEGER NOT NULL AUTO_INCREMENT,**
-> **FAMALY VARCHAR(35),**
-> **NAME VARCHAR(30),**
-> **OTCHESTVO VARCHAR(35),**

-> **DESCRIPTION BLOB,**
-> **PHOTOFILE BLOB,**
-> **EMAIL VARCHAR(40),**
-> **ZVANIE VARCHAR(34),**
->**DOLGNOST VARCHAR(40),**
-> **PRIMARY KEY (NUMBER)**
-> **);**
Query OK, 0 rows affected (0.06 sec)

Now that the table is created, the SHOW TABLES command should output the following:

mysql>**SHOW TABLES;**

```
+--------------------+
| Tables_in_perpetuum |
+--------------------+
| TABLE1             |
+--------------------+
1 row in set (0.00 sec)
```

1 row in set (0.00 sec)

To check if the table was created correctly according to the plan, you can use the DESCRIBE command:

mysql>**DESCRIBE pet;**

```
+---------+------------+------+-----+---------+-------+
| Field   | Type       | Null | Key | Default | Extra |
+---------+------------+------+-----+---------+-------+
| name    | varchar(20)| YES  |     | NULL    |       |
| owner   | varchar(20)| YES  |     | NULL    |       |
| species | varchar(20)| YES  |     | NULL    |       |
| sex     | char(1)    | YES  |     | NULL    |       |
| birth   | date       | YES  |     | NULL    |       |
| death   | date       | YES  |     | NULL    |       |
+---------+------------+------+-----+---------+-------+
```

You can use the DESCRIBE command at any time, for example, if you forget the column names or the types to which they belong.

mysql>**describe TABLE1;**

```
  +-----------+------------+------+-----+---------+----------+
| Field       | Type        | Null | Key | Default | Extra     |
  +-----------+------------+------+-----+---------+----------+
| NUMBER      | int(11)     |      | PRI | NULL |auto_increment|
| FAMALY      | varchar(35) | YES  |     | NULL    |            |
| NAME        | varchar(30) | YES  |     | NULL    |            |
| OTCHESTVO   | varchar(35) | YES  |     | NULL    |            |
| DESCRIPTION | blob        | YES  |     | NULL    |            |
| PHOTOFILE   | blob        | YES  |     | NULL    |            |
| EMAIL       | varchar(40) | YES  |     | NULL    |            |
| ZVANIE      | varchar(34) | YES  |     | NULL    |            |
| DOLGNOST    | varchar(40) | YES  |     | NULL    |            |
  +-----------+------------+------+-----+---------+----------+
```

9 rowsinset (0.02 sec)

Loading data into a table

Having created a table, you need to fill it with data. To do it you can use the LOAD DATA and INSERT commands .

mysql>**INSERT INTO TABLE1 VALUES (NULL,**
->**'Nurbekov', 'Dias', 'Muratovich',**
->**'coobic', NULL, 'nur_bek@mail.ru'**,
->**NULL, NULL);**
Query OK, 1 row affected (0.03 sec)

For the system to work properly you need the following pre-installed software: Apache Web Server, PHP 4.3.x, MySql, on the FreeBSD or Linux platform. You can also install the system on the Windows platform. To work with the client part of the system, you need a computer connected via TCP / IP to the network in which the MySQL server is located

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УПРАВЛЕНИЕ БАЗАМИ ДАННЫХ MYSQLИ ЭТАПЫ РАЗРАБОТКИ КЛИЕНТ-СЕРВЕРНОЙ ИНФОРМАЦИОННОЙ СИСТЕМЫ С ИСПОЛЬЗОВАНИЕМ MYSQL

Аннотация: В работе рассматривается различные аспекты и обязанности администрирования на базе данных MySQL основные обязанности и методические инструкции, основные вопросы и обязанности управления программное обеспечение MySQL могут использоваться любым пользователем. Поэтому в статье приводится методы службы модификации и утилизацию. Также приводятся внутренняя характеристика и способности, рабочие платформы и копирование базы данных, возможность резервирования удаляющихся данных, этапы обработки данных технологией клиент-сервер, обработанные в связи с пользователем MySQL предлагают большими возможностями по технической характеристике MySQL-это система клиент-сервер, он включает многопоточный SQL-сервер, а также поддерживает базы данных вычислительных машин, программы и библиотеки, инструменты администрирования, предлагает расширенный программный интерфейс. Приведены типы данных и методы создания таблиц. Развитие систем базы данных облегчает процедуру инсталляции и применение MySQL. MySQL обеспечивает простоту работы между пользователями.

Рассмотрены основные компоненты СУБД MySQL. Как известно, MySQL является реляционной системой управления базами данных. В реляционной системе базы данных не все данные сохраняются, но многие данные сохраняются в отдельных таблицах. Поэтому в данной работе рассматриваются методы работы с таблицами, которые могут облегчить работу в MySQL. Рассматриваются вопросы MySQL как структурированный язык запросов на SQL.

Ключевые слова: MySQL, администратор баз данных, разработка ИС по технологии клиент сервер, базы данных, типы базы данных MySQL

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MYSQLДЕРЕКТЕР ҚОРЫН БАСҚАРУ МЕН ОНЫ ҚОЛДАНЫП КЛИЕНТ-СЕРВЕРЛІК АҚПАРАТТЫҚ ЖҮЙЕНІ ӨҢДЕУ ЭТАПТАРЫ

Аннотация. Мақалада MySQL администрирлеудің түрлі аспектілері мен міндеттерді сәтті орындауға меңгеруге қажет негізгі сұрақтар қарастырылады. Администратордың негізгі міндеттері мен оны орындау нұсқаулықтары, MySQL басқарудың негізгі сұрақтары мен басқарушының міндеттері мен MySQL бағдарламалық қамсыздандыруы- кез-келген адам оны қолдануына және модифицирлеуіне болатын ашық кодты бағдарламалық қамсыздандыру жайлы айтылады. MySQL клиенттік программалары мен утилиталарының қызметтеріне шолу жасалады. Ішкі сипаттамасы мен қабілеттілігі, жұмыс жасау платформалары мен деректер қорын көшіру және резервтеудегі ақпараттың жойылуы. Сонымен қоса ақпараттық жүйені клиент-сервер технологиясы бойынша өңдеу этаптары. Қолданушымен тығыз қатынасқа өңделген MySQL бірқатар ыңғайлы мүмкіндіктері, MySQL қолданушымен тығыз қатынаудың бірқатар мүмкіндіктеріне ие. Техникалық сипаттамалары бойынша MySQL клиент-серверлік жүйе, көплегті SQL-серверді ендіреді, түрлі есептеуіш машиналар деректер қорларын қолдайды, сонымен қатар клиентті бағдарламалар мен кітапханаларды, администрирлеу құралдары мен бағдарламалық интерфейстің кеңейтілген спектрін ұсынады. Деректер типтері мен оларды кесте құруда қолдану жазылған. Деректер қоры жүйелерінің дамуы инсталляциялау процедурасы мен MySQL қолдану жеңілдей түседі. MySQL жұмыстың қарапайымдылығы қолданушылар арасындағы кеңінен қолданудың себебі болғандығы жайлы қарастырылады.

Түйін сөздер: MySQL, деректер қоры администраторы, клиент-сервер технологиясы бойынша АЖ өңдеу, деректер қоры, MySQL деректер қорының типтері.

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APPROXIMATE SOLUTION OF THE AN ELASTIC LAYER VIBRATION TASK BEING EXPOSED OF MOVING LOAD

Annotation: The present work is devoted to the dynamics stability study of wave processes of plane and circular elements, and it is also being considered a class of plane tasks about moving loads effect on the surface of a layered elastic half-plane under the nonlinear law of stress versus deformation. While studying the wave processes of planar and circular elements in deformable bodies, the concept of phase velocity is introduced as the rate of phase medium change. In the case of harmonic vibrations of a cylindrical shell, the phase speed is expressed through the frequency of natural oscillations of freely supported along the edges of the shell, and therefore, the investigation of waves in plane and circular elements has the most direct relation to the problem of determining the own forms and vibration frequencies of finite length shells. If the studies are carried out taking into account the material rheological properties of considered system, there is a surrounding system environment, also generally displaying rheological properties, the use of these methods is considerably difficult. In such cases, the influence of rheological parameters on the components of the complex phase velocity is studied in definite values of the vibration frequencies. At present article, it is being considered an approximate solution of the nonlinear task about the effect of a moving load on an elastic layer lying on an undeformable base under the nonlinear stress law of depending strains from deformations.

Key words: stability, dynamics, mobile loading, harmonic oscillations, deformation, rheology, oscillation, purity, wave processes.

While solving the problems of wave processes of plane and circular elements in deformable bodies, the concept of phase velocity is introduced as the rate of change of the phase medium. In this case of harmonic vibrations of a cylindrical shell, the phase velocity is expressed through the frequency of natural oscillations freely supported along the edges of the shell, and therefore, the investigation of waves in plane and circular elements has the most direct relation to the problem of determine the proper forms and vibration frequencies of finite length shells.

In many studies, two methods are usually used to determine the characteristics of waves.

It is studied the instantaneous state of the medium, corresponding to a certain fixed time moment.

It is studied the change in time of the body constant state at some fixed point.

If the studies are carried out taking into account the rheological properties of the considered system material or, there is a surrounding medium, also generally displaying rheological properties, the use of these methods is considerably difficult. In such cases, the influence of rheological parameters on the components of the complex phase velocity is studied for certain values of the vibration frequencies.

The physical law of stress-strain relation in a plane formulation is adopted in the form

$$\sigma_{jj} = 3K\varepsilon_0\left[1+\alpha x_0\varepsilon_0^2\right] + 2\mu\left(\varepsilon_{jj}-\varepsilon_0\right)\left[1+\alpha\gamma_0\psi_0^2\right];$$
$$\sigma_{ij} = \mu\varepsilon_{ij}\left[1+\alpha\gamma_0\psi_0^2\right], \quad \left(i \neq j; i, j = x, y\right) \tag{1}$$

где $\varepsilon_0;\psi_0$ - average volumetric strain and intensity of strain rate α - small parameter.

Oscillations in a layer are boundary conditions:

$$\sigma_{yy} = f_y(x,t), \quad \sigma_{xy} = 0, \ \ y = h,$$
$$v = 0, \ \ \sigma_{xy} = 0, \ \ y = 0. \tag{2}$$

Due to the boundary conditions, the longitudinal displacement u is an even function of the coordinate and a transverse movement v odd in x.

Therefore, we will continue these functions on y from $-h$ to 0.

Then, instead of the problem for an elastic layer lying on an undeformable base, we obtain the task for a thickness layer $2h(-h \le y \le h)$, on the surface of which $y = \pm h$ external forces are set

$$\sigma_{yy} = f(x,t), \ \sigma_{xy} = 0. \tag{3}$$

However, in such a formulation the problem remains very complicated in the mathematical formulation and obtaining its solution presents great difficulties. This problem can be solved in an approximate formulation, considering the elastic layer as an elastic thickness plate $2h$.

Approximate equation of the longitudinal vibration of a plate in a nonlinear setting for the main part of the longitudinal displacement U has the following form:

$$\frac{\partial^2 U}{\partial t^2} - C_{пл}^2 \frac{\partial^2 U}{\partial x^2} - \frac{2}{9}\alpha \frac{x_0 k}{\rho}\left(\frac{4\mu - \rho C_{пл}^2}{4\mu}\right)^4 \frac{\partial}{\partial x}\left[\left(\frac{\partial U}{\partial x} + \right.\right.$$
$$\left.\left. + \frac{1}{\mu} f_y\right)^3\right] = \frac{1}{\rho}\left(\frac{\rho C_{пл}^2}{2\mu} - 1\right)\frac{\partial f_y}{\partial x} \tag{4}$$

Let us consider a special case of an external rolling effort, when:

$$f_y(x,t) = f_y(x - Dt), \tag{5}$$

where D - the speed of movement of the external load on the surface layer is considered constant.

We introduce the moving coordinate

$$x' = x - Dt, \tag{6}$$

and for simplicity x, y we omit the primes.

In moving coordinates, the longitudinal vibration of elastic layer or plate with the physical nonlinearity of the law $\sigma(\varepsilon)$ with allowance for the external mobile load is described by the following nonlinear ordinary equation:

$$\left(D^2 - \tilde{N}_{ïë}^2\right)\frac{d^2 U}{dx^2} - \frac{2}{9}\alpha \frac{x_0 k}{\rho}\left(\frac{4\mu - \rho c_{ïë}^2}{4\mu}\right)^4 \frac{d}{dx}\left[\left(2\frac{dU}{dx} + \right.\right.$$
$$\left.\left. + \frac{f_y}{\mu}\right)^3\right] = \frac{1}{\rho}\left(\frac{\rho \tilde{N}_{ïë}^2}{2\mu} - 1\right)\frac{\partial f_y}{\partial x} \tag{7}$$

obtained from the (4) when replacing (6).

Integrating (7) on x, taking into account the damping condition at infinity

Relatively $\frac{dU}{dx}$ we obtain a cubic equation:

$$\left(\frac{dU}{dx}\right)^3+\frac{3}{2\mu}f_y\left(\frac{dU}{dx}\right)^2+\left[\frac{3}{4\mu^2}f_y^2-\frac{9\rho\left(D^2-C_{\text{пл}}^2\right)}{16\alpha x_0 k}\left(\frac{4\mu}{4\mu-\rho C_{\text{пл}}^2}\right)^4\right]\times$$

$$\times\frac{dU}{dx}+\left[\frac{1}{8\mu^3}f_y^3-\frac{9\left(2\mu-\rho C_{\text{пл}}^2\right)}{32\alpha\mu x_0 k}\left(\frac{4\mu}{4\mu-\rho C_{\text{пл}}^2}\right)^4 f_y\right]=0 \tag{8}$$

Substitution

$$\frac{dU}{dx}=S-\frac{a}{3};$$

the equation(8) is reduced to the form:

$$S^3+PS+q=0, \tag{9}$$

where: $a=\frac{3}{2\mu}f_y$,

$$P=-\frac{9\rho\left(D^2-C_{\text{ïё}}^2\right)}{16\alpha x_0 k}\left(\frac{4\mu}{4\mu-\rho C_{\text{ïё}}^2}\right)^4,$$

i.e. P does not depend on external load a

$$q=-\frac{9\left(2\mu-\rho C_{\text{ïё}}^2\right)}{32\alpha\mu x_0 k}\left(\frac{4\mu}{4\mu-\rho C_{\text{ïё}}^2}\right)^4 f_y.$$

Let us consider the case when $\alpha<0$ (similarly, the problem is solved in the case $\alpha>0$).
If we consider the excess sound mode

$$D>C_{\text{ïё}}$$

i.e. when the perturbation in the layer before the load is absent, it is clear that $P>0$ and the equation(9) (respectively (8)) has one real solution.

If the speed of movement of an external load D satisfies the inequality

$$D<C_{\text{ïё}}$$

i.e subsonic mode,then $P<0$ and the equation (9) (respectively(8)) can have another solution.

One real solution of equation (8) in the subsonic mode has the form:

$$\frac{dU}{dx}=\sqrt[3]{-\frac{q(x)}{2}+\sqrt{\left(\frac{p}{3}\right)^3+\left(\frac{q(x)}{2}\right)^2}}+\sqrt[3]{-\frac{q(x)}{2}-\sqrt{\left(\frac{p}{3}\right)^3+\left(\frac{q(x)}{2}\right)^2}}-\frac{a(x)}{3}. \quad (10)$$

Integrating (10) X with respect to the damping condition of the displacement at infinity, and the transition to the fixed coordinates, we obtain:

$$U=\int_{\infty}^{x-Dt}\left[\sqrt[3]{-\frac{q(\xi)}{2}+\sqrt{\left(\frac{p}{3}\right)^3+\left(\frac{q(\xi)}{2}\right)^2}}+\sqrt[3]{-\frac{q(\xi)}{2}-\sqrt{\left(\frac{p}{3}\right)^3+\left(\frac{q(\xi)}{2}\right)^2}}-\frac{a(\xi)}{3}\right]d\xi \quad (11)$$

The magnitude of the voltage σ_{xx} is approximately calculated by the formula:

$$\sigma_{xx}=\rho C_{ïё}^2\left[\sqrt[3]{-\frac{q(x-Dt)}{2}+\sqrt{\left(\frac{p}{3}\right)^3+\left(\frac{q(x-Dt)}{2}\right)^2}}+\sqrt[3]{-\frac{q(x-Dt)}{2}-\sqrt{\left(\frac{p}{3}\right)^3+\left(\frac{q(x-Dt)}{2}\right)^2}}\right]-$$
$$-f_y(x-Dt)-\alpha\left[\left(\frac{\rho C_{ïё}^2}{2\mu}-1\right)f_2(U)-f_1(U)\right], \quad (12)$$

where,

$$f_2(U)=\frac{1}{9}x_0k\left(\frac{4\mu-\rho C_{пл}^2}{4\mu}\right)^3\left(2\frac{\partial U}{\partial x}+\frac{1}{\mu}f_y\right)^3;$$

$$f_1(U)=\frac{1}{9}x_0k\left[2\left(1-\frac{\rho C_{пл}^2}{4\mu}\right)\frac{\partial U}{\partial x}+\frac{1}{\lambda+2\mu}f_y-\frac{\alpha}{\lambda+2\mu}f_2(U)\right]^3.$$

From the last expressions it follows that when $\alpha\to 0$ we obtain a solution for the linear problem.

If the non-linearity parameter α is assumed sufficiently small, then instead of (11) we can approximately use the formula for displacement:

$$U=\frac{1}{\rho\left(D^2-C_{ïё}^2\right)}\left(\frac{\rho C_{ïё}^2}{2\mu}-1\right)\int_{\infty}^{x-Dt}f_y(\xi)d\xi+\alpha\left\{\frac{2}{9}\frac{x_0k}{\rho\left(D^2-C_{ïё}^2\right)}\times\right.$$
$$\left.\times\left(\frac{4\mu-\rho C_{пл}^2}{4\mu}\right)^4\left[\frac{\rho D^2-2\mu}{\mu\rho\left(D^2-C_{пл}^2\right)}\right]^3\int_{\infty}^{x-Dt}f_y^3(\xi)d\xi\right\} \quad (13)$$

At small α values for the voltage $\sigma_{xx},\sigma_{yy},\sigma_{xy}$ formulas are obtained:

$$\sigma_{xx}=\frac{D^2}{D^2-C_{ïё}^2}\left(\frac{\rho C_{ïё}^2}{2\mu}-1\right)f_y+\alpha\left\{\frac{2}{9}\frac{x\,kC_{ïё}^2}{D^2-C_{ïё}^2}\times\left(\frac{4\mu-\rho C_{ïё}^2}{4\mu}\right)^4\left[\frac{\rho D^2-2\mu}{\mu\rho\left(D^2-C_{ïё}^2\right)}\right]^3f_y^3+2\left(1-\frac{\rho C_{ïё}^2}{4\mu}\right)f_2(U)\right\}+$$

$$+\frac{y^2}{2}\left\{\left[\rho D^2\left(\frac{\rho C_{пл}^2}{2\mu}+1\right)-\rho D^2\left(\frac{\rho C_{пл}^2}{2\mu}-1\right)^2+3(\lambda+2\mu)\left(\frac{\rho C_{пл}^2}{2\mu}-2\right)-2\left(\rho C_{пл}^2-3\mu\right)\right]\frac{\partial^3 U}{\partial x^3}+\right.$$

$$+\frac{1}{\lambda+2\mu}\left[\rho D^2\left(\frac{\rho C_{пл}^2}{2\mu}-1\right)+4\mu-3(\lambda+2\mu)\right]\frac{\partial^2 f_y}{\partial x^2}-$$

$$\left.-\frac{\alpha}{\lambda+2\mu}\left[\rho D^2\left(\frac{\rho C_{пл}^2}{2\mu}-1\right)+4\mu-3(\lambda+2\mu)\right]\frac{\partial^2 f_2(U)}{\partial x^2}-\alpha\frac{4\mu}{4\mu-\rho C_{пл}^2}\frac{\partial^2 f_2(U)}{\partial x^2}\right\}; \tag{14}$$

$$\sigma_{zz}=f_y+\frac{y^2-h^2}{2}\left\{\frac{\rho C_{пл}^2}{2\mu}\left(\rho D^2-2\mu\right)\frac{\partial^3 U}{\partial x^3}-\left(\frac{\rho D^2}{\lambda+2\mu}+\frac{\rho C_{пл}^2}{2\mu}-1\right)\frac{\partial^2 f_y}{\partial x^2}+\right.$$

$$\left.+\alpha\left(\frac{\rho D^2}{\lambda+2\mu}+\frac{\rho C_{пл}^2}{2\mu}-2\right)\frac{\partial^2 f_2(U)}{\partial x^2}\right\};$$

$$\sigma_{xz}=\alpha+\left(y-\frac{1}{h^2}y^3\right)\frac{x_0 k}{192}\left(\frac{4\mu-\rho C_{ïë}^2}{\mu}\right)^4\left[\frac{\rho D^2-2\mu}{\mu\rho\left(D^2-C_{ïë}^2\right)}\right]^3 f_z^2 f_z^1 .$$

If $f_z(x-Dt)$ given as

$$f_y(x-Dt)=\sigma_0\beta(x-Dt)l^{-\beta(x-Dt)}, \tag{15}$$

then, for example, with respect to the dimensionless relation $\frac{\sigma_{xx}}{\sigma_0}$ approximately obtain:

$$\frac{\sigma_{xx}}{\sigma_0}=l_1\xi l^{-\xi}+\alpha l_2\sigma_0^2\xi^3 l^{-3\xi},\ (\alpha<0), \tag{16}$$

where,

$$l_1=\frac{D^2}{D^2-C_{пл}^2}\left(\frac{\rho C_{пл}^2}{2\mu}-1\right)>0,$$

$$l_2=\frac{D^2}{D^2-C_{пл}^2}\cdot\frac{x_0 k\left(4\mu-\rho C_{пл}^2\right)^4\left(\rho D^2-2\mu\right)}{1152\mu^7\rho^3\left(D^2-C_{пл}^2\right)^3}>0$$

The present work is devoted to the dynamics stability study of wave processes of plane and circular elements, and it is also being considered a class of plane tasks about moving loads effect on the surface of a layered elastic half-plane under the nonlinear law of stress versus deformation. A class of plane problems on the effect of moving loads on the surface of a layered elastic half-plane is solved. The problems of this class are of great practical interest and, in addition, can serve as a standard for the development of various numerical algorithms for solving dynamic problems.

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ҚОЗҒАЛМАЛЫ ЖҮКТЕМЕНІҢ ӘСЕРІНЕН ПАЙДА БОЛАТЫН, СЕРПІМДІ ҚАБАТТЫҢ ТЕБЕЛІС ЕСЕБІНІҢ ЖУЫҚ ШЕШІМІ

Аннотация. Бұл мақала дөңгелек және жазық элементтердің толқындық процсстер кезінде орын алатын орнықтылық динамикасын зеріттеуге арналған, және де осыған қоса кернеудің деформациядан сызықтық емес заңы бойынша, қатпарлы тұрқыр бетімен қозғалмалы үстеме жағдайындағы, тәуелділігінің жазық есептер топтамасын қарастырады. Деформацияланатын денелердің дөңгелек және жазық элементтерінің толқындық процсстерін зерттеу кезінде фазалық жылдамдық, фазалық ортаның жылдамдығының өзгеру шамасы деген ұғым енгізіледі. Цилиндрлік қабықшалардың гармоникалық тербелісі жағдайында фазалық жылдамдық, қабықшалардың шеттерінде еркін орналасқан өзіндік тербеліс жиілігі арқылы өрнектеледі, сондықтан дөңгелек және жазық элементтер толқынын зерттеу, қабықшаның ақырлы ұзындығының жиілік тербелісі мен дербес формасын анықтауға тікелей байланысты. Егер зарттеу жұмысы қарастырылып отырған жүйе материалдың реологиялық қасиеті негігінде жүргізілсе немесе, қоршаған орта жүйесі болса, және жалпы жағдайда реологиялық қасиеттері анықталса онда бұл тәсілдерді қолдану қыйынға соғады.

Түйін сөздер: орнықтылық, динамика, жылжымалы жүктеме, гармониялық тербелістер, деформация, реология, тербеліс, жиілік, толқындық процестер.

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ПРИБЛИЖЕННОЕ РЕШЕНИЕ ЗАДАЧИ О КОЛЕБАНИИ УПРУГОГО СЛОЯ, ПОДВЕРГАЮЩЕГОСЯ ВОЗДЕЙСТВИЮ ПОДВИЖНОЙ НАГРУЗКИ

Аннотация: Данная работа посвящена изучению динамики устойчивости волновых процессов плоских и круговых элементов, а также рассматривается класс плоских задач о воздействии подвижных нагрузок на поверхность слоистой упругой полуплоскости при нелинейном законе зависимости напряжений от деформаций. При исследованиях волновых процессов плоских и круговых элементов в деформируемых телах вводится понятие фазовой скорости, как скорости изменения фазовой среды. В случае гармонических колебаний цилиндрической оболочки фазовая скорость выражается через частоту собственных колебаний свободно опертой по краям оболочки, и поэтому, исследование волн в плоских и круговых элементах имеет самое прямое отношение к проблеме определения собственных форм и частот колебаний оболочек конечной длины. Если исследования проводятся с учетом реологических свойств материала рассматриваемой системы или, имеется окружающая систему среда, также в общем случае, проявляющая реологические свойства, использование этих способов значительно затруднено. В таких случаях изучается влияние реологических параметров на составляющие комплексной фазовой скорости при определенных значениях частот колебаний.

Ключевые слова: устойчивость, динамика, подвижная нагрузока, гармоническая колебания, деформация, реология, колебание, чистота, волновые процессы

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INTERACTIVE VIRTUALIZATION IN THE ENVIRONMENT OF FLASH-CC, JAVA SCRIPT OF ALGORITHMS OF MATHEMATICAL COMMUNICATIONS THE PHENOMENON OF GEOMETRICAL OPTICS

Abstract. The geometrical optics – considers light distribution, by means of laws of geometry. A light beam is called the line along which light energy is transferred. The geometrical optics allows to formulate the theory of optical systems with relief. The geometrical optics, generally allows to find optical images, optical systems to calculate an aberration of beams, a beam of light in advanced methods, their adjustment, optical systems and their emergence which pass through the power relations. Nevertheless, qualities of the image, all wave phenomena by means of optical devices and also the size of the diffraction phenomenon are considered in optics. Many tasks of the theory of optical installations are based on laws of geometrical optics. In this work, algorithms of mathematical communications of geometrical optics, i.e. laws of reflection and refraction of light beams, are considered on the studied installation when passing light through the planes of border of two dielectric environments. Optical processes on border of these optical environments are visualized and online are virtualized by means of the computer program Adobe Flash-CC environments. The made, laboratory work on a research of processes of geometrical optics is very effective at development of this course. This virtual interactive laboratory development is introduced in educational process of the Eurasian technological university and is successfully applied in training.

Keywords: Algorithm, virtual integration, geometrical optics, turn, lens corners, dielectric, mathematical functions.

Introduction. Were not defined completely light nature yet, the following laws of optics were known: The law of rectilinear distribution of light – light rays in optically homogeneous environment extends on a straight line of lines. Light rays are lines on which light energy is transferred. In the homogeneous environment light rays provide themselves straight lines of lines. The law of independence of a light bunch – effect of a separate bunch of light rays, does not depend on effect of other bunches of light rays, i.e. bunches of light rays do not influence at each other. Concept of independence of distribution of light rays appeared in ancient science. Ancient Greek erudite Euclid formulated rectilinear distribution of light rays its laws of reflection from mirrors. In the 17th century the invention of a number of optical instruments as a long glass, a microscope, the telescope, etc. also their broad application was an incitement to development of ray optics. The Dutch mathematician V. Snell and Frenchman R. Dekart experimentally defined laws of distribution of light rays on a demarcation of two optical medium. Theoretical fundamentals of ray optics, at the end of 17th centuries located after opening of a Fermat's principle. Earlier opened laws of distribution of light on a straight line of lines, laws of reflection of beams were a consequence of this principle [1].

Many tasks of the theory of optical instruments and installations were tilled today based on laws of ray optics.

In this work, laws of reflection and refraction of light rays, algorithms of mathematical communications, are considered virtually on the computer on an optical bench, on border of the plane of the section of two dielectric environments. Optical processes on the plane of a demarcation of two environments are visualized and the virtual are carried interactively out on the computer by means of the computer program Adobe Flash environments – CC. The developed virtual laboratory works are very effective when studying ray optics. The called virtual laboratory works are introduced in educational process and are successfully applied at the Eurasian Technological University.

Interactive tools and virtualization on the computer of laws of ray optics program is environment Flash-CC, Java - script.

The present requirement of time for transfer larger volume information on the Internet, including animation images in movements and work with them demands the large volume of memory. And for reduction of capacity of use of memory use for the virtual – interactive tools of Flash technologies is very efficient. [3,4]. From the basic vector and graphical Flash format of technologies – a branch was created. But, it is not the first vector format; it is the Web broadcast mechanism – pages to SWF as finding of the graphic representation, the coordinating link of an instrumental inventory and the graphic representation. Advantage of SWF-of the application it is easily an acceptability on other place, i.e. this format is used in different is information – the program platform (in the Mac OS Macintosh operating system, in OS - Windows OS). One more feature of SWF – the constructed main images not only accept animation but also are padding, an opportunity to create interactive elements and audio of installation. Besides, mathematical formula communications of physical processes can be turned into interactive elements, management of their changes give the chance, to carry out on the computer, interactive virtual researches. For example, as shown in the drawing that the mathematical dependences found Snellius for reflection and light refraction and to form interactive virtual laboratory, very conveniently the formats SWF, CC of them – the program Flash environment. For transfer on distances of interactive multimedia additions are carried out on the known SWF format – in the Web application for the Internet. Why, to emergence of this application of this format in Macromedia, for browsers of two main networks of the Plug in component, and to distribution to Enternet Explorer and Nestcape Communicator the worldwide computer network affected. One more reason popularity of SWF – a format is very mild and convenient application instruments for other platforms development of Macromedia. For example creations of the multimedia presentations using the program device – Macromedia Director Shockwave Studio, - and applied the program device to creation of graphic images – Macromedia Authorwave, Macromedia Course Builder. Therefore among Web – the publication the most recognizable and easily applied publication is Macromedia Flash Web – gives the chance to decorate each website with animation and to collect the complete page. Action Script Tools - allows to collect Web addition efficiently and its modern languages similarly probably on the scenario Java Script, Action Script and by means of the editor of Devigger is the solution of often applied elements. When there is a work of Flash – you can construct the collected clip or import graphics, later in process of work will be able to process and by means of an assembly ruler to use effect of resuscitation (Time line) [4]. Such clip or the movie can be interactive, i.e. particular images can be changed at discretion and to influence events in the clip. You export it in the Flash format, adding the page, and transfer to the page as the Web – the server. Each clip or the movie collected by tools in the Flash system can change depending on a type of the carried-out tasks and it can be seen via the browser of the Internet. Practically, for interactive visualization and management, on the computer, the pilot unit and devices, set the object which is carried out by means of computer programs in the environment of Flash. For example, for realization of following operations, the computer program is written in the environment of Flash – CC:

- to install devices or to clean from devices. Pressing the left-hand button of a mouse, it is possible to open any door of a case with devices directing the cursor to devices and for the second time pressing the first button of a mouse, it is possible to install devices on an optical bench (figure 1). To clean an optical bench, to direct the cursor to devices, mice press the right button and once again the button - switch off window parameters. The button "Start-up" - is intended for switching off of consecration of laboratory and start-up of the pilot unit. The button "Feet " - switch off the pilot unit and includes consecration of laboratory. Directing the cursor to books, it is possible to obtain necessary information on laboratory work and to change language for choice.

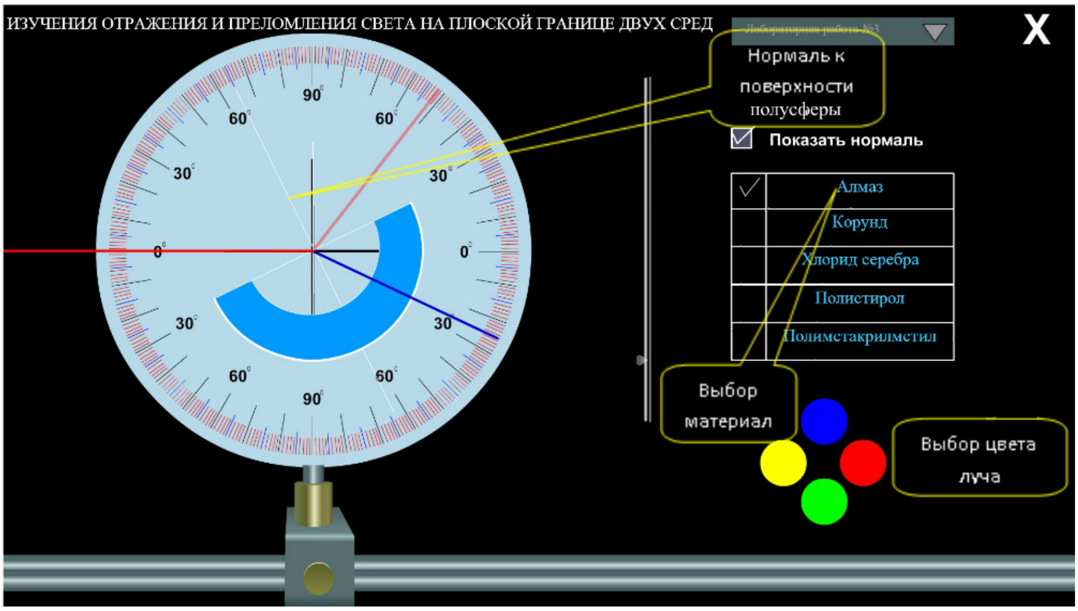

Figure 1 - Installation for a research of laws of reflection and refraction on flat limit of sections of two environments

Change of an angle of incidence of a light ray. As shown in the figure 1 to direct the cursor to the changeable site, pressing the left-hand button of a mouse, it is possible to change an angle of incidence and reflections of a beam concerning a perpendicular. Pressing the right button of a mouse, it is possible to change parameters of a light ray and material of the environment. Pressing two times in a row the left-hand button of a mouse it is possible to switch off installation. Installation for a research of distribution of a light ray in the environment with a changeable index of refraction. Here actions of management of measurement of parameters are also similar; it is possible to measure an angle of incidence of an emergent beam. Installation actions of management of measurement of parameters are also similar; it is possible to change an angle of incidence of the entering beam, to change the place of an entrance of an incident beam.

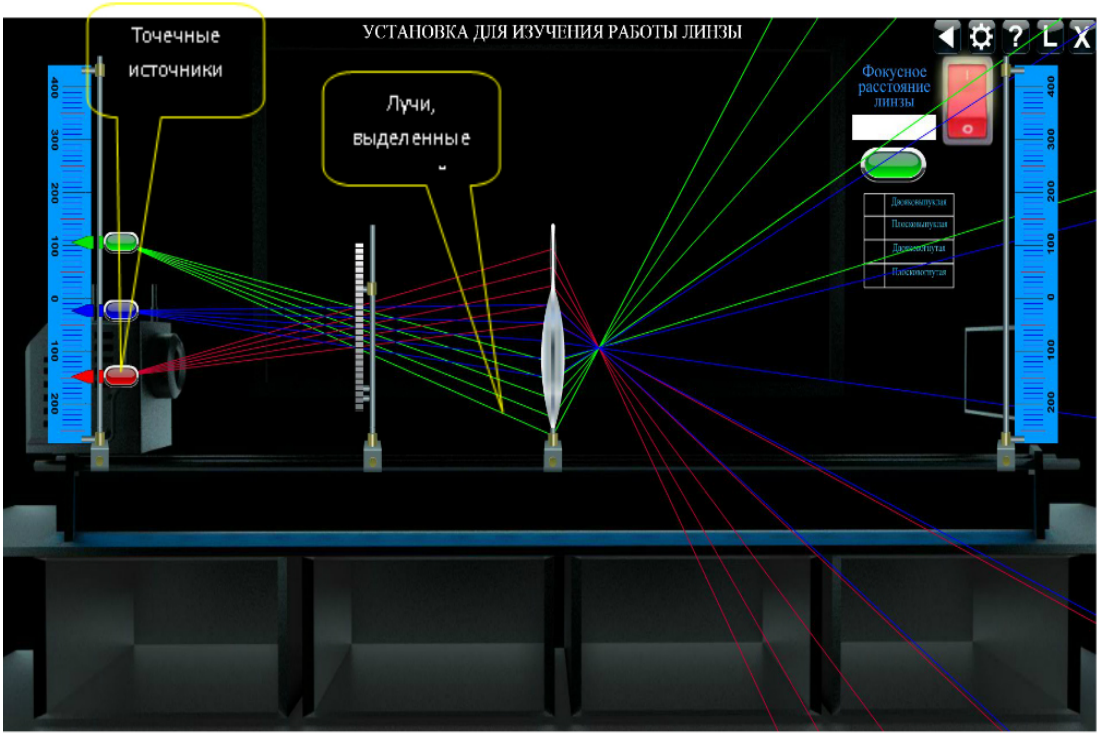

Figure 2 - Installation for a research of work of various lenses. Interactive tools of a research of an optical lens with various focal distances, and a research of parameters of a convex, seven convex, and dispersing lens.

Here are provided:
- changes of location of light sources of various lengths of waves across;
- change of location of light sources of various lengths of waves of a vertical;
- change of parameters of lenses (forms, focal distances, imaginary light sources and their beams).
- a research of the course of light rays of various wavelength in the collecting lens.

Conclusion.

As a part of informational technologies the new branch develops - it is the virtual interactive tools and visualization of the hardly understood subjects of physics, chemistry, biology and other objects [5]. And creation is virtual – interactive laboratories on called a subject meet the operated measuring apparatuses very seldom. Therefore the technology of creation of the virtually-interactive laboratory (VIL) for the section of physics given in this work. "The optics - ray optics" will be very relevant to creators similar to VIL – at higher step in other objects of knowledge. Such VIL – on the computer are very effective for development of a particular course of knowledge and develop self-contained research skills and awaken to creative searching of research techniques. Given VIL on ray optics, due to rituality and interactive intervention in change process an experiment condition, it is very useful to fast development of a subject of physics by students and to development of skills researching it. Brought VIL – on ray optics are introduced in educational process of the Eurasian Technological University and are successfully applied there.

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ГЕОМЕТРИЯЛЫҚ ОПТИКА ҚҰБЫЛЫСТАРЫНЫҢ МАТЕМАТИКАЛЫҚ БАЙЛАНЫСТАР АЛГОРИТМІН FLASH-CC, JAVA SCRIPT-, БАҒДАРЛАУ ОРТАЛАРЫНДА ИНТЕРБЕЛСЕНДІ ВИРТУАЛДАУ

Аннотация. Геометриялық оптика- оптиканың жарықты геометрия сызық ретінде қарастыра отырып, жарықтың таралу заңдарын зерттейтін бөлімі. Сызық бойымен жарық энергиясы ағыны таралатын геометриялық сызық- жарық сәулесі деп аталады. Геометриялық оптика заңдары көп ретте оптикалық жүйелердің жеңілдетілген, бірақ көп жағдайда дәл теориясын жасауға мүмкіндік береді. Геометриялық оптика, негізінен, оптикалық кескіннің пайда болуын түсіндіреді, оптикалық жүйелер аберрацияларын есептеп шығаруға және оларды түзету әдістерін жетілдіруге, оптикалық жүйелер арқылы өтетін сәулелер шоғының энергетикалық қатысын табуға мүмкіндік береді. Дегенмен, барлық толқындық құбылыстар, сондай-ақ, кескіннің сапасына ықпал ететін және оптикалық приборлардың ажыратқыштық шамасын анықтайтын дифракциялық құбылыстар геометриялық оптикада қарастырылмайды.

Оптикалық құрылғылар теориясының көптеген есептері осы кезге дейін геометриялық оптикаға негізделген.

Бұл жұмыста, геометриялық оптиканың шағылу, сыну заңдарының математикалық байланыс алгоритмін, зерттеу қондырғысы екі диэлектірлік ортаның жазық шекарасында қарастырылады. Осы ортаның шекарасындағы оптикалық процестер Adobe Flash-CC- бағдарламалық ортасында іске асырылған.

Жасалынған зертханалық жұмыс геометриялық оптиканы игеру нәтижесінде зор пайда келтіреді. Аталынған зертханалық жұмыс Еуразия технологиялық университетінің оқу процесіне ендіріліп, қолданыста пайдаланылуда.

Тірек сөздер: Алгоритм, виртуалды интербелсенді, геометриялық оптика, сыну, шағылу бұрыштары, жұқа линзалар, диэлектрлік, математикалық функционалды байланыстар.

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ИНТЕРАКТИВНАЯ ВИРТУАЛИЗАЦИЯ В СРЕДЕ FLASH-CC, JAVA SCRIPT- АЛГОРИТМОВ МАТЕМАТИЧЕСКИХ СВЯЗЕЙ ЯВЛЕНИИ ГЕОМЕТРИЧЕСКОЙ ОПТИКИ

Аннотация. Геометрическая оптика – рассматривает распространение света, с помощью законов геометрии. Световым лучом называется линия, вдоль которой переносится световая энергия. Геометрическая оптика позволяет облегченно сформулировать теорию оптических систем. Геометрическая оптика, в основном, позволяет найти оптические изображения, оптические системы вычислить аберрацию лучей, пучка света в усовершенствованных методах, их корректировку, оптические системы и их возникновения, которые проходят через энергетические отношения. Тем не менее, рассматриваются в оптике, качества изображения, все волновые явления с помощью оптических приборов, а также величина дифракционного явления. Многие задачи теории оптических установок основаны на законах геометрической оптики. В данной работе, алгоритмы математических связей геометрической оптики, т.е. законов отражения и преломления световых лучей, рассматриваются на исследуемой установке при прохождении света через плоскости границы двух диэлектрических сред.

Оптические процессы на границе этих сред визуализированы и интерактивно виртуализированы с помощью компьютерных программных сред Adobe Flash-CC. Сделанная, лабораторная работа по исследованию процессов геометрической оптики очень эффективна при освоении данного курса, а технология создания ВИЛ описанной в данной статье, очень актуальна для создания аналогичных виртуально-интерактивных лаборатории по другим предметам.

Данная виртуально- интерактивная лабораторная разработка внедрена в учебный процесс Евразийского технологического университета и успешно применяется в обучении.

Ключевые слова: Алгоритм, виртуальное интегрирование , геометрическая оптика, поворот, углы линзы, диэлектрик, математические функции.

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THE COMPLETENESS OF THE NONCOMMUTATIVE $H_E(\mathrm{A}, \ell_\infty)$ SPACE

Abstract. Considering the commutative case, we know that a maximal function $f = \sup_n |f_n|$ belongs to $L_p(\mu)$ if and only if there is a factorization $f_n = cz_n = z_n c$ for all $n \in \mathbb{N}$, where $c \in L_p(\mu)$ and $\sup_n \|z_n\|_\infty < \infty$. The theory of vector-valued noncommutative L_p-spaces are introduced first time by Pisier in 1998. Pisier considered the case M is hyperfinite. This theory solved maximal function's problem in noncommutative case. Later in 2002 Junge and Xu introduced general case. By using these noncommutative vector valued L_p-spaces Junge solved noncommutative version of Doob's maximal inequality problem in general case.

The noncommutative vector-valued Hardy spaces were introdused in [2]. In this paper, we consider maximal function's problems on noncommutative Hardy spaces. For this reason we introduce a noncommutative vector-valued symmetric Hardy space.

Our aim is discover their properties. It is presented another useful proof of completeness of this space. We also obtain factorization theorem like Saito's theorem. The work is mostly theoretical. The results can be used to further develop of noncommuative martingale theory, noncommutative ergodic theory, and operator valued Hardy spaces theory.

Key words: von Neumann algebra, τ -measurable operator, subdiagonal algebra, noncommutative symmetric space, noncommutative Hardy space.

1 Preliminaries and Introduction

Let $S(0,1)$ be the space of all measurable real-valued functions on $(0,1)$ equipped with Lebesgue measure m (functions which coincide almost everywhere are considered identical).

For $x \in S(0,1)$ we denote by $\mu(x)$ the decreasing rearrangement of the function $|x|$. That is,

$$\mu(t,x) = \inf\{s \geq 0 : m(\{|x| > s\}) \leq t\}, \quad t > 0.$$

Definition 1 We say that $(E, \|\cdot\|_E)$ is a symmetric Banach function space if the following holds.

(a) E is a subset of $S(0,1)$.

(b) $(E, \|\cdot\|_E)$ is a Banach space.

(c) If $x \in E$ and if $y \in S(0,1)$ are such that $|y| \leq |x|$, then $y \in E$ and $\|y\|_E \leq \|x\|_E$.

(d) If $x \in E$ and if $y \in S(0,1)$ are such that $\mu(y) = \mu(x)$, then $y \in E$ and $\|y\|_E = \|x\|_E$.

Furthermore we recall that the norm in E is said to be order continuous if, for every sequence $\{x_n\}_{n\geq 0} \subset E$ such that $x_n \downarrow 0$ in $S(0,1)$, we have that $\|x_n\|_E \to 0$. Order continuity of the norm is equivalent to separability of the space E (see [10]).

Special examples of such Banach function spaces are the spaces $L_p(0,1)$, $1 \le p \le \infty$, equipped with their usual norm $\|\cdot\|_p$.

We recall that every symmetric Banach function space satisfies

$$L_\infty(0,1) \subset E \subset L_1(0,1)$$

with continuous embeddings.

We say that y is submajorized by x in the sense of Hardy-Littlewood (written $y \preccurlyeq x$) if

$$\int_0^t \mu(s,y)ds \le \int_0^t \mu(s,x)ds, \quad t > 0.$$

Now let E be a Banach lattice. Let $0 < r < \infty$. Then E is said to be r-convex and r-concave, if there exists a constant $C > 0$ such that for all finite sequence (x_n) in E

$$\left\| \left(\sum_{k=1}^n |x_k|^r \right)^{1/r} \right\|_E \le C \left(\sum_{k=1}^n \|x_k\|_E^r \right)^{1/r},$$

and

$$\left(\sum_{k=1}^n \|x_k\|_E^r \right)^{1/r} \le C \left\| \left(\sum_{k=1}^n |x_k|^r \right)^{1/r} \right\|_E,$$

and as usual the best constant $C > 0$ is denoted by $M^{(r)}(E)$ and $M_{(r)}(E)$, respectively. We recall that for $r_1 \le r_2$ we have

$$M^{r_1}(E) \le M^{r_2}(E)$$

and

$$M_{r_2}(E) \le M_{r_1}(E).$$

For all needed information on convexity and concavity we once again refer to [10]. If $M^{\max(1,r)}(E) = 1$, then the r'th power

$$E^r := \{x \in L_0(\Omega) : |x|^{1/r} \in E\}$$

endowed with the norm

$$\|x\|_{E^r} = \left\| |x|^{1/r} \right\|_E^r$$

is again a Banach function space which is $1/\min(1,r)$-convex.

Let $\mathbf{H}$ be a Hilbert space. The closed densely defined linear operator x in $\mathbf{H}$ with domain $D(x)$ is said to be affiliated with M if and only if $uxu = x$ for all unitary operators u which belong to the commutant M' of M. An operator x affiliated with M is said to be $\tau-$measurable, if for every $\varepsilon > 0$ there exists a projection e in M such that $e(\mathbf{H}) \subseteq D(x)$ and $\tau(1-e) < \varepsilon$. The set of all τ-measurable operators will be denoted by $L_0(\mathrm{M})$. The set $L_0(\mathrm{M})$ is a $*$-algebra with sum and product being the respective closure of the algebraic sum product [12]. For each x on $\mathbf{H}$ affiliated with M, all spectral projection $e_s^\perp(|x|) = \chi_{(s;\infty)}(|x|)$ corresponding to the interval $(s;\infty)$ belong to M, and $x \in L_0(\mathrm{M})$ if and only if $\chi_{(s;\infty)}(|x|) < \infty$ for some $s \in \mathbf{R}$. Recall the decreasing rearrangement (or generalized singular numbers) of an operator $x \in L_0(\mathrm{M})$ is defined as follows

$$\mu(t,x) = \inf\{s > 0 : \lambda_s(x) \le t\},\ t > 0$$

where

$$\lambda_s(x) = \tau(e_s^{\perp}(|x|)), s > 0.$$

The function $s \mapsto \lambda_s(x)$ is called the distribution function of x. For more details on generalized singular value function of measurable operators we refer to [7]. Recall the construction of a Banach symmetric operator space $L_E(\mathcal{M}, \tau)$ (for convenience $L_E(\mathcal{M})$). Let E be a Banach symmetric function space. Set

$$L_E(\mathcal{M}, \tau) = \{x \in L_0(\mathcal{M}, \tau) : \mu(x) \in E\}.$$

We equip $L_E(\mathcal{M}, \tau)$ with a natural norm

$$\|x\|_{L_E(\mathcal{M},\tau)} = \|\mu(x)\|_E, \quad x \in E(\mathcal{M}, \tau).$$

It was further established in [15] that $E(\mathcal{M}, \tau)$ is Banach.

Since for each operator $x \in L_0(\mathcal{M})$

$$\mu(|x|^r) = \mu(x)^r,$$

we conclude for every symmetric Banach function space E on the interval $(0,1)$ which satisfies $M^{\max(1,r)}(E) = 1$ that

$$L_{E^r}(\mathcal{M}) := \{x \in L_0(\mathcal{M}) : |x|^{1/r} \in L_E(\mathcal{M})\}$$

and

$$\|x\|_{L_{E^r}(\mathcal{M})} = \|\mu(|x|)\|_{E^r} = \|\mu(|x|^{1/r})\|_E^r = \||x|^{1/r}\|_{L_E(\mathcal{M})}^r.$$

See [3, 5].

Let $\mathcal{M}$ be a finite von Neumann algebra on the Hilbert space $\mathbf{H}$ equipped with a normal faithful tracial state τ. Let $\mathcal{D}$ be a von Neumann subalgebra of $\mathcal{M}$, and let $\Phi : \mathcal{M} \to \mathcal{D}$ be the unique normal faithful conditional expectation such that $\tau \circ \Phi = \tau$. A finite subdiagonal algebra of $\mathcal{M}$ with respect to Φ is a w^*-closed subalgebra $\mathcal{A}$ of $\mathcal{M}$ satisfying the following conditions:

(i) $\mathcal{A} + J(\mathcal{A})$ is w^*-dense in $\mathcal{M}$;

(ii) Φ is multiplicative on $\mathcal{A}$, i.e., $\Phi(ab) = \Phi(a)\Phi(b)$ for all $a, b \in \mathcal{A}$;

(iii) $\mathcal{A} \cap J(\mathcal{A}) = \mathcal{D}$, where $J(\mathcal{A})$ is the family of all adjoint elements of the element of $\mathcal{A}$, i.e., $J(\mathcal{A}) = \{a^* : a \in \mathcal{A}\}$.

The algebra $\mathcal{D}$ is called the diagonal of $\mathcal{A}$. It is proved by Exel [6] that a finite subdiagonal algebra $\mathcal{A}$ is automatically maximal in the sense that if $\mathcal{B}$ is another subdiagonal algebra with respect to Φ containing $\mathcal{A}$, then $\mathcal{B} = \mathcal{A}$.

For brevity, we introduce the following definition which was defined in [1].

Definition 2 *Let E be a symmetric Banach space on $(0,1)$ and $\mathcal{A}$ be a finite subdiagonal subalgebra of $\mathcal{M}$. Then $H_E(\mathcal{A}) = [\mathcal{A}]_{L_E(\mathcal{M})}$ called symmetric Hardy space associated with $\mathcal{A}$, where $[\cdot]_{L_E(\mathcal{M})}$ means closure in the norm of $L_E(\mathcal{M})$. We denote $[\mathcal{A}_0]_{L_E(\mathcal{M})}$ by $H_E^0(\mathcal{A})$.*

The theory of vector-valued non-commutative L_p-spaces were introduced by Pisier in [11] for the case, when $\mathcal{M}$ is hyperfinite and Junge introduced these spaces for general setting in [8] (see also [4, 9]). The theory for the space $L_E(\mathcal{M}; \ell_\infty)$ was developed by Defant in [3] and Dirksen in [5] and in full analogy with the special case $L_E = L_p$ considered in [4, 8, 9]. In fact, most of the basic results follow verbatim as soon as were replaced L_p by L_E, $L_{p'}$ by $L_{E^\times}$, where $1/p + 1/p' = 1$, and L_{2p} by $L_{E^{1/2}}$ in the proofs of those results.

Let us denote by $L_E(\mathrm{M};\ell_\infty)$ the space of all families $x=(x_n)_{n\geq 1}$ in $L_E(\mathrm{M},\tau)$ for which there are operators $a,b\in L_{E^{1/2}}(\mathrm{M})$ and a uniformly bounded sequence $(y_n)_{n\geq 1}$ in M such that there is a factorization $x_n=ay_nb$ for all $n\in\mathbf{N}$. We set

$$\|x\|_{L_E(\mathrm{M};\ell_\infty)}:=\inf\{\|a\|_{L_{E^{1/2}}(\Box)}\sup_n\|y_n\|_\infty\|b\|_{L_{E^{1/2}}(\mathrm{M})}\},$$

where the infimum is taken over all such possible factorizations. Moreover, we denote by $L_E(\mathrm{M};\ell_\infty^{col})$ (here "col" should remind on the word "column") the space of all $x=(x_n)_{n\geq 1}$ in $L_E(\mathrm{M})$ for which there are $b\in L_E(\mathrm{M})$ and a bounded sequence $(y_n)_{n\geq 1}$ in M such that $x_n=y_nb$ for all n. We then put

$$\|x\|_{L_E(\mathrm{M};\ell_\infty^{col})}:=\inf\{\sup\|y_n\|_\infty\|b\|_{L_E(\mathrm{M})}\}.$$

Similarly, the row version consisting of all families $x=(x_n)_{n\geq 1}$ admitting a factorization $x_n=ay_n$ with $a\in L_E(\mathrm{M})$ and $(y_n)_{n\geq 1}$ bounded in M is denoted by $L_E(\mathrm{M};\ell_\infty^{row})$ and we define

$$\|x\|_{L_E(\mathrm{M};\ell_\infty^{row})}:=\inf\{\|a\|_{L_E(\mathrm{M})}\sup\|y_n\|_\infty\}.$$

In both cases the infimum is again taken over all possible factorizations.

Now we define the analogue of this space by a similar way.

Definition 3 *We define* $H_E(\mathrm{A};\ell_\infty)$ *as the space of all sequences* $x=(x_n)_{n\geq 1}$ *in* $H_E(\mathrm{A})$ *which admit a factorization of the following form: there are* $a,b\in H_{E^{1/2}}(\mathrm{A})$, *and a bounded sequence* $y=(y_n)\subset \mathrm{A}$ *such that*

$$x_n=ay_nb,\forall n\geq 1. \tag{1}$$

Given $x\in H_E(\mathrm{A},\ell_\infty)$ define

$$\|x\|_{H_E(\mathrm{A};\ell_\infty)}:=\inf\{\|a\|_{H_{E^{1/2}}(\mathrm{A})}\sup_n\|y_n\|_\infty\|b\|_{H_{E^{1/2}}(\mathrm{A})}\}, \tag{2}$$

where the infimum runs over all factorizations of (x_n) as above. Moreover, let us define $H_E(\mathrm{A};\ell_\infty^{col})$ as the space of all $(x_n)_{n\geq 1}$ in $H_E(\mathrm{A})$ for which there are $b\in H_E(\mathrm{A})$ and bounded sequence $(y_n)_{n\geq 1}$ in M such that $x_n=y_nb$ and

$$\|x\|_{H_E(\mathrm{A};\ell_\infty)}:=\inf\{\sup_n\|y_n\|_\infty\|b\|_{H_E(\mathrm{A})}\}. \tag{3}$$

Similarly, we define the row version $H_E(\mathrm{A};\ell_\infty^{row})$ all sequences which allow a uniform factorization $x_n=ay_n$, again with $a\in H_E(\mathrm{A})$ and $(y_n)_{n\geq 1}$ uniformly bounded in M.

This space with $H_p(\mathrm{A};\ell_\infty)$ was introduced in the paper [13, 14, 2] with some basic properties.

Section 1 contains some preliminary definitions. In section 2, we prove that $H_E(\mathrm{A},\ell_\infty)$ is Banach space.

2 Main results

Theorem 1*Let* E *be an* r*-convex symmetric Banach space on* $(0,1)$ *for some* $0<r<\infty$. *Assume* E *does not contain* c_0. *Then* $H_E(\mathrm{A},\ell_\infty)$ *is Banach space.*

Proof. Let us first check that $\|\cdot\|_{H_E(\mathrm{A},\ell_\infty)}$ satisfies triangle inequality. Let $(h_n^{(1)}),(h_n^{(2)})\in H_E(\mathrm{A},\ell_\infty)$, choose a factorization of $h^{(j)}$ with $j=1,2$:

$$h_n^{(j)}=a^{(j)}x_n^{(j)}b^{(j)},\ \forall n$$

such that

$$\left\|a^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}=\left\|b^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}=\left\|(h_n^{(j)})\right\|_{H_E(\mathrm{A},\ell_\infty)}^{\frac{1}{2}}$$

and

$$\sup_n\left\|x_n^{(j)}\right\|_\infty\leq 1+\varepsilon,\ \ j=1,2. \tag{4}$$

Indeed, for any $\varepsilon>0$ choose a factorization $h_n^{(j)}=c^{(j)}y_n^{(j)}d^{(j)}$, $\forall n\geq 1$ with $j=1,2$ such that

$$c^{(j)}\in H_{E^{1/2}}(\mathrm{A}),\ d^{(j)}\in H_{E^{1/2}}(\mathrm{A}),\sup_n\left\|y_n^{(j)}\right\|_\infty=\alpha$$

and

$$\left\|h_n^{(j)}\right\|_{H_E(\mathrm{A},\ell_\infty)}(1+\varepsilon)\geq\left\|\alpha^{\frac{1}{2}}c^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}\sup_n\left\|\frac{y_n^{(j)}}{\alpha}\right\|_\infty\left\|\alpha^{\frac{1}{2}}d^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}. \tag{5}$$

Then by choosing

$$a^{(j)}=\frac{\alpha^{\frac{1}{2}}\left\|(h_n^{(j)})\right\|_{H_E(\mathrm{A},\ell_\infty)}^{1/2}c^{(j)}}{\left\|\alpha^{\frac{1}{2}}c^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}},b^{(j)}=\frac{\alpha^{\frac{1}{2}}\left\|(h_n^{(j)})\right\|_{H_E(\mathrm{A},\ell_\infty)}^{1/2}d^{(j)}}{\left\|\alpha^{\frac{1}{2}}d^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}}$$

and

$$x_n^{(j)}=\frac{\left\|\alpha^{\frac{1}{2}}c^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}\left\|\alpha^{\frac{1}{2}}d^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}y_n^{(j)}}{\alpha\left\|(h_n^{(j)})\right\|_{H_E(\mathrm{A},\ell_\infty)}},$$

we obtain

$$a^{(j)}x_n^{(j)}b^{(j)}=c^{(j)}y_n^{(j)}d^{(j)}=h_n^{(j)},j=1,2$$

and

$$\left\|a^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}=\left\|h_n^{(j)}\right\|_{H_E(\mathrm{A},\ell_\infty)}^{1/2},$$

$$\left\|b^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}=\left\|h_n^{(j)}\right\|_{H_E(\mathrm{A},\ell_\infty)}^{1/2}.$$

Let $a^{(j)}=|(a^{(j)})^*|u^{(j)}$ and $b^{(j)}=v^{(j)}|b^{(j)}|$ be the polar decompositions of $(a^{(j)})^*$ and $b^{(j)}$, respectively. Then $u^{(j)}x_n^{(j)}v^{(j)}\in\mathrm{M}$, so we can substitute $x_n^{(j)}$ by $u^{(j)}x_n^{(j)}v^{(j)}$ and therefore we are allowed to assume that the $a^{(j)}$ and $b^{(j)}$ are positive for $j=1,2$. Define operators: $a:=(|(a^{(1)})^*|^2+|(a^{(2)})^*|^2+\varepsilon)^{\frac{1}{2}}$ and $b:=(|b^{(1)}|^2+|b^{(2)}|^2+\varepsilon)^{\frac{1}{2}}$;

clearly,

$$\left\|a\right\|_{E^{\frac{1}{2}}(\mathrm{A})}^2\leq(\left\|(a^{(1)})^*\right\|_{E^{\frac{1}{2}}(\mathrm{A})}^2+\left\|(a^{(2)})^*\right\|_{E^{\frac{1}{2}}(\mathrm{A})}^2+\varepsilon)^{\frac{1}{2}}$$

$$=(\left\|(h_n^{(1)})\right\|_{H_E(\mathrm{A},\ell_\infty)}+\left\|(h_n^{(2)})\right\|_{H_E(\mathrm{A},\ell_\infty)}+\varepsilon)^{\frac{1}{2}},$$

a similar inequality holds for b with norm $\|\cdot\|_E^{\frac{1}{2}}$. By Remark 2.3 in [4] there exist contractions $\omega^{(j)},\theta^{(j)}\in\mathrm{M}$ such that $|(a^{(j)})^*|=a(\omega^{(j)})^*,|b^{(j)}|=\theta^{(j)}b$ and

$$(\omega^{(1)})^*\omega^{(1)}+(\omega^{(2)})^*\omega^{(2)}=r(a^2),(\theta^{(1)})^*\theta^{(1)}+(\theta^{(2)})^*\theta^{(2)}=r(b^2).$$

And, since $a^{-1},b^{-1}\in\mathrm{M}$ and $(a^{-1})^{-1}=a,b\in L_E(\mathrm{M})$, by Proposition 4.3. (i) in [1] there exist the unitary operators $\nu^{(1)},\nu^{(2)}\in\mathrm{M}$ and $w^{(1)},w^{(2)}\in\mathrm{A}$ such that $a^{-1}=\nu^{(1)}w^{(1)}$ and $b^{-1}=w^{(2)}\nu^{(2)}$, where $(w^{(1)})^{-1},(w^{(2)})^{-1}\in H_{E^{1/4}}(\mathrm{A})$. Obviously,

$$\begin{aligned}h_n^{(1)}+h_n^{(2)}&=(w^{(1)})^{-1}[(\nu^{(1)})^{-1}(\omega^{(1)})^*u^{(1)}x_n^{(1)}\nu^{(1)}\theta^{(1)}\\&\quad+(\omega^{(2)})^*u^{(2)}x_n^{(2)}\nu^{(2)}\theta^{(2)}(\nu^{(2)})^{-1}](w^{(2)})^{-1}.\end{aligned}$$

Define the sequence

$$y_{(\cdot)}:=(\nu^{(1)})^{-1}(\omega^{(1)})^*u^{(1)}x_{(\cdot)}^{(1)}\nu^{(1)}\theta^{(1)}+(\omega^{(2)})^*u^{(2)}x_{(\cdot)}^{(2)}\nu^{(2)}\theta^{(2)}(\nu^{(2)})^{-1}.$$

Since $y_n=(w^{(1)})^{-1}[h_n^{(1)}+h_n^{(2)}](w^{(2)})^{-1}\in H_r(\mathrm{A})$ by Proposition 4.3. (ii) in [1] $y_n\in H_r(\mathrm{A})\cap\mathrm{M}=\mathrm{A}$. Consider for each fixed n the following mapping:

$U:\mathbf{M}_2(\mathrm{M})\to\mathbf{M}_2(\mathrm{M})$

defined by

$$U(X)=\begin{pmatrix}(\omega^{(1)})^* & (\omega^{(2)})^*\\ 0 & 0\end{pmatrix}\begin{pmatrix}u^{(1)} & 0\\ 0 & u^{(2)}\end{pmatrix}X\begin{pmatrix}\nu^{(1)} & 0\\ 0 & \nu^{(2)}\end{pmatrix}\begin{pmatrix}\theta^{(1)} & 0\\ \theta^{(2)} & 0\end{pmatrix},$$

where

$$X=\begin{pmatrix}y_n^{(1)} & 0\\ 0 & y_n^{(2)}\end{pmatrix}\in\mathbf{M}_2(\mathrm{M}).$$

We need to show that $\|y_n\|\le 1$.

Indeed,

$$\begin{aligned}\|y_n\|&=\left\|(\nu^{(1)})^{-1}[(\omega^{(1)})^*u^{(1)}x_n^{(1)}\nu^{(1)}\theta^{(1)}+(\omega^{(2)})^*u^{(2)}x_n^{(2)}\nu^{(2)}\theta^{(2)}](\nu^{(2)})^{-1}\right\|\\&=\left\|(\omega^{(1)})^*u^{(1)}x_n^{(1)}\nu^{(1)}\theta^{(1)}+(\omega^{(2)})^*u^{(2)}x_n^{(2)}\nu^{(2)}\theta^{(2)}\right\|=\|U(X)\|\\&\le\left\|\begin{pmatrix}(\omega^{(1)})^* & (\omega^{(2)})^*\\ 0 & 0\end{pmatrix}\right\|\left\|\begin{pmatrix}u^{(1)} & 0\\ 0 & u^{(2)}\end{pmatrix}\right\|\|X\|\left\|\begin{pmatrix}\nu^{(1)} & 0\\ 0 & \nu^{(2)}\end{pmatrix}\right\|\left\|\begin{pmatrix}\theta^{(1)} & 0\\ \theta^{(2)} & 0\end{pmatrix}\right\|\\&\le\|\omega_1^*\omega_1+\omega_2^*\omega_2\|^{\frac{1}{2}}\|\theta_1^*\theta_1+\theta_2^*\theta_2\|^{\frac{1}{2}}\le\|r(a^2)\|^{\frac{1}{2}}\|r(b^2)\|^{\frac{1}{2}}\le 1.\end{aligned}$$

So,

$$\|(h_n^{(1)}+h_n^{(2)})\|_{H_E(\mathrm{A},\ell_\infty)}\le\|c\|_{H_{E^{1/2}}(\mathrm{A})}\sup_n\|y_n\|\|d\|_{H_{E^{1/2}}(\mathrm{A})}$$

$$\le(\||(c^{(1)})^*|^2\|_{H_{E^{1/4}}(\mathrm{A})}+|\|(c^{(2)})^*|^2\|_{H_{E^{1/4}}(\mathrm{A})}+\varepsilon)^{\frac{1}{2}}(\||d^{(1)}|^2\|_{H_{E^{1/4}}(\mathrm{A})}+\||d^{(2)}|^2\|_{H_{E^{1/4}}(\mathrm{A})}+\varepsilon)^{\frac{1}{2}}$$

$$\le(\|c^{(1)}\|^2_{H_{E^{1/2}}(\mathrm{A})}+\|c^{(2)}\|^2_{H_{E^{1/2}}(\mathrm{A})}+\varepsilon)^{\frac{1}{2}}(\|d^{(1)}\|^2_{H_{E^{1/2}}(\mathrm{A})}+\|d^{(2)}\|^2_{H_{E^{1/2}}(\mathrm{A})}+\varepsilon)^{\frac{1}{2}}$$

$$=\|(h_n^{(1)})\|_{H_E(\mathrm{A},\ell_\infty)}+\|(h_n^{(2)})\|_{H_E(\mathrm{A},\ell_\infty)}+\varepsilon.$$

Then letting $\varepsilon\to 0$, we obtain the desired triangle inequality. To show the completeness, we take a Cauchy sequence $(h^{(j)})\in H_E(\mathrm{A},\ell_\infty)$ for which we may assume without loss of generality that for all k

$$\left\|(h^{(j)}-h^{(j+1)})\right\|_{H_E(\mathrm{A},\ell_\infty)}<\frac{2^{-3j}}{2},\qquad (j=1,2...).$$

Define for each N the sequences

$$\eta^N_{(\cdot)}:=\sum_{j=N}^{\infty}h^{(j+1)}_{(\cdot)}-h^{(j)}_{(\cdot)}$$

in $H_E(\mathrm{A})$.

First,we need to show that all of them belong to $H_E(\mathrm{A},\ell_\infty)$ for all N and that

$$\left\|\eta^N\right\|_{H_E(\mathrm{A},\ell_\infty)}\le 2^{-N+1}.$$

Let

$$h^{(j)}-h^{(j+1)}=a^{(j)}x^{(j)}_{(\cdot)}b^{(j)}$$

with

$$\left\|a^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}\le 2^{-j},\left\|b^{(j)}\right\|_{H_{E^{1/2}}(\mathrm{A})}\le 2^{-j},\sup_n\left\|x^{(j)}_n\right\|_\infty\le 2^{-j}.$$

As above, we may assume that $a^{(j)}$ and $b^{(j)}$ are positive, obviously

$$\sum_{j=1}^{\infty}|(a^{(j)})^*|^2\in H_{E^{1/4}}(\mathrm{A}),\ \sum_{j=1}^{\infty}|b^{(j)}|^2\in H_{E^{1/4}}(\mathrm{A})$$

and

$$\left\|\sum_{j=1}^{\infty}|(a^{(j)})^*|^2\right\|_{H_{E^{1/4}}(\mathrm{A})}\le\sum_{j=1}^{\infty}\left\||(a^{(j)})^*|^2\right\|_{H_{E^{1/4}}(\mathrm{A})}=$$

$$\sum_{j=1}^{\infty}\left\||(a^{(j)})^*\right\|^2_{H_{E^{1/2}}(\mathrm{A})}\sum_{j=1}^{\infty}\left\|a^{(j)}\right\|^2_{H_{E^{1/2}}(\mathrm{A})}\le\sum_{j=1}^{\infty}2^{-2j}\le 1;$$

similarly,

$$\left\|\sum_{j=1}^{\infty}|b^{(j)}|^2\right\|_{H_{E^{1/4}}(\mathrm{A})}\le\sum_{j=1}^{\infty}\left\||b^{(j)}\right\|^2_{H_{E^{1/2}}(\mathrm{A})}=\sum_{j=1}^{\infty}\left\|b^{(j)}\right\|^2_{H_{E^{1/2}}(\mathrm{A})}\le 1.$$

Define $a:=(\sum_{j=1}^{\infty}|(a^{(j)})^*|^2+\varepsilon)^{\frac{1}{2}}\in H_{E^{1/2}}(\mathrm{A})$ and $b:=(\sum_{j=1}^{\infty}|b^{(j)}|^2+\varepsilon)^{\frac{1}{2}}\in H_{E^{1/2}}(\mathrm{A})$, then

$$\left\|a\right\|_{H_{E^{1/2}}(\mathrm{A})}=\left\|\sum_{j=1}^{\infty}|(a^{(j)})^*|^2+\varepsilon\right\|^{\frac{1}{2}}_{H_{E^{1/4}}(\mathrm{A})}$$

$$\le(\left\|\sum_{j=1}^{\infty}|(a^{(j)})^*|^2\right\|_{H_{E^{1/4}}(\mathrm{A})}+\varepsilon)^{\frac{1}{2}}=\sum_{j=1}^{\infty}\left\|a_j\right\|^2_{H_{E^{1/2}}(\mathrm{A})}+\varepsilon\le 1+\varepsilon$$

and

$$\left\|b\right\|_{H_{E^{1/2}}(\mathrm{A})}\le 1+\varepsilon.$$

So by letting $\varepsilon\to 0$, we obtain $\left\|a\right\|_{H_{E^{1/2}}(\mathrm{A})}\le 1$ and $\left\|b\right\|_{H_{E^{1/2}}(\mathrm{A})}\le 1$. Let $a^{(j)}=|(a^{(j)})^*|u^{(j)}$ and $b^{(j)}=v^{(j)}|b^{(j)}|$. On the other hand, according to Remark 2.3 in [4] there exist contractions $\omega^{(j)},\theta^{(j)}\in\mathrm{M}$ such that $|(a^{(j)})^*|=a(\omega^{(j)})^*$ and $|b^{(j)}|=\theta^{(j)}b$ as above. Thus

$$\zeta_{(\cdot)}^N=\sum_{j=N}^{\infty}(\omega^{(j)})^*u^{(j)}x_{(\cdot)}^{(j)}v^{(j)}\theta^{(j)}.$$

Hence $\sup_n\left\|\eta_n^N\right\|_\infty\le 2^{-(N-1)}$. So we obtain

$$\left\|\zeta_{(\cdot)}^N\right\|\le\sum_{j=N}^{\infty}\left\|(\omega^{(j)})^*u^{(j)}x_{(\cdot)}^{(j)}v^{(j)}\theta^{(j)}\right\|\le\sum_{j=N}^{\infty}\left\|x_{(\cdot)}^{(j)}\right\|\le\sum_{j=N}^{\infty}2^{-j}\le 2^{-(N-1)}$$

and

$$\eta_n^N=\sum_{j=N}^{\infty}a^{(j)}x^{(j)}b^{(j)}=\sum_{j=N}^{\infty}|(a^{(j)})^*|u^{(j)}x_n^{(j)}v^{(j)}|b^{(j)}|$$

$$=\sum_{j=N}^{\infty}a(\omega^{(j)})^*u^{(j)}x_n^{(j)}v^{(j)}\theta^{(j)}b=a(\sum_{j=N}^{\infty}(\omega^{(j)})^*u^{(j)}x_n^{(j)}v^{(j)}\theta^{(j)})b=a\zeta^N b.$$

Hence

$$\eta^N\in H_E(\mathrm{A};\ell_\infty)$$

and

$$\left\|\eta^N\right\|_{H_E(\mathrm{A};\ell_\infty)}\le\left\|a\right\|_{H_{E^{1/2}}(\mathrm{A})}\sup_n\left\|\zeta_n^N\right\|_\infty\left\|b\right\|_{H_{E^{1/2}}(\mathrm{A})}\le 2^{-(N-1)}.$$

So

$$\left\|\sum_{k=1}^{N}(h^{(k+1)}-h^{(k)})-\eta^1\right\|_{H_E(\mathrm{A};\ell_\infty)}=\left\|\eta^{N+1}\right\|_{H_E(\mathrm{A};\ell_\infty)}\le 2^{-N}\to 0,$$

$$as\ N\to\infty$$

$$\sum_{k=1}^{N}(h^{(k+1)}-h^{(k)})\to\eta^1.$$

Therefore we get $h^{(N+1)}\to h^{(1)}+\eta^1$ conclusion.

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КОММУТАТИВТІ ЕМЕС $H_E(\mathrm{A},\ell_\infty)$ КЕҢІСТІГІНІҢ ТОЛЫҚТЫҒЫ

Аннотация. Коммутативті жағдайды қарастыра отырып, $f=\sup_n|f_n|$ максималды функциясы $L_p(\mu)-$ға тәуелді болса, сонда тек сонда ғана барлық $n\in\mathbb{N}$ үшін $f_n=cz_n=z_nc$ факторизациялауы бар болады, мұндағы $c\in L_p(\mu)$ және $\sup_n\|z_n\|_\infty<\infty$. Вектор–мәнді коммутативті емес L_p-кеңістіктерінің теориясын 1998 жылы алғаш рет Писье енгізген. Писье M -гиперақырлы болған жағдайын қарастырған. Бұл теория коммутативті емес жағдайда максималды функция мәселесін шешті. Кейінірек 2002 жылы Юнге және Шүй жалпы жағдайда енгізген. Осы вектор-мәнді коммутативті емес L_p-кеңістіктерін пайдаланып, Юнге жалпы жағдайда Дубтың максималды теңсіздік мәселесінің коммутативті емес нұсқасын шешті.

Коммутативті емес вектор-мәнді Харди кеңістіктері [2]-де енгізілді. Осы мақалада Коммутативті емес Харди кеңістіктерінде максималды функцияның мәселелерін қарастырамыз. Сол себепті біз коммутативті емес вектор-мәнді симметриялық Харди кеңістіктерін енгіземіз.

Біздің мақсатымыз олардың қасиеттерін көрсету. Бұл кеңістіктің толықтығын дәлелдейтін тағы бір пайдалы дәлел келтірілген. Сондай-ақ, Сайто теоремасы ұқсайтын факторизациялық теореманы аламыз. коммутативті емес мартингал теориясы, коммутативті емес эргодик теориясы және оператор мәнді Харди кеңістіктер теориясы үшін қолдануға болады.

Түйін сөздер: Фон Нейман алгебрасы, τ - өлшемді оператор, субдиагональді алгебра, коммутативты емес симметрикалық кеңістік, коммутативты емес Харди кеңістігі.

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ПОЛНОТА НЕКОММУТАТИВНОГО ПРОСТРАНСТВО $H_E(\mathrm{A},\ell_\infty)$

Аннотация. Рассматривая коммутативный случай, мы знаем, что максимальная функция $f=\sup_n|f_n|$ принадлежит $L_p(\mu)$ тогда и только тогда, когда существует факторизация $f_n=cz_n=z_nc$ для всех $n\in\mathbb{N}$, где $c\in L_p(\mu)$ и $\sup_n\|z_n\|_\infty<\infty$. Теория вектор-значных некоммутативных L_p-пространств впервые вводится Письеом в 1998 году. Писье считал случай M гиперконечным. Эта теория решала задачу максимальной функции в некоммутативном случае. Позднее в 2002 году Юнге и Сюй представили общий случай. Используя эти некоммутативные векторнозначные L_p-пространства, Юнге решил некоммутативный вариант максимальной задачи неравенства Дуба в общем случае.

Некоммутативные векторнозначные пространства Харди были интродуцированы в [2]. В настоящей работе рассматриваются задачи максимальной функции на некоммутативных пространствах Харди. По этой причине мы вводим некоммутативное вектор-симметричное симметричное пространство Харди.

Наша цель - открыть их свойства. Представлено еще одно полезное доказательство полноты этого пространства. Мы также получаем теорему факторизации, такую как теорема Сайто. Работа в основном теоретическая. Результаты могут быть использованы для дальнейшего развития некоммутативной теории мартингалов, некоммутативной эргодической теории и операторнозначной теории пространств Харди.

Ключевые слова: алгебра Фон Неймана, τ -измеримый оператор, поддиагональная алгебра, некоммутативное симметричное пространство, некоммутативное пространство Харди.

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THE STUDY OF THE NEUTRON HALO OF THE ^{11}BE NUCLEUS TAKING INTO ACCOUNT THE INFLUENCE OF AN EXTERNAL FIELD

Abstract. The aim of work is theoretical study of the Coulomb breakup of halo nuclei in time-dependent quantum-mechanical approach. Exotic nuclei are the subject of intensive experimental research.Theoretical studies of Coulomb breakup of halo nuclei are relevant for the interpretation and planning of experiments for the study of light nuclei on radioactive beams.The investigations with beams of radioactive nuclei have opened new prospects in studying the structure of the atomic nucleus and have found wide applications in other areas of physics, including nuclear astrophysics. The halo is one of the most intensively studied objects in modern low-nucleus physics. A characteristic feature of halo nuclei physics is correlations between the mechanism of nuclear reaction and structure.

The breakup is one of the important tools for theoretical study of the properties of halo nuclei. In these reactions, the information from the breakup of the projectile into fragments can be used to make a conclusion about the properties of the halo part of the wave function. With good approximation, the breakup could be considered as transition from bound state of two (three) particles to the continuum, due to changing Coulomb field.

In this paper, the energy levels of the halo nucleus of^{11}Be are calculated, taking into account the effect of an external magnetic field. The ^{11}Be nucleus is regarded as a neutron halo consisting of ^{10}Be core and one neutron. This work is the initial stage of the work on the investigation of the breakup of halo nuclei in the quantum-mechanical approach.

Key words: Halo nucleus, Coulomb breakup, breakup cross section, exotic states of the nuclei, nonstationary Schrödinger equation, energy spectrum, nuclear potential.

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ИЗУЧЕНИЕ НЕЙТРОННОГО ГАЛО ЯДРА ^{11}ВЕ С УЧЕТОМ ВЛИЯНИЯ ВНЕШНЕГО ПОЛЯ

Аннотация. Цельюработыявляетсятеоретическое исследование процессов кулоновского развала гало ядер в рамках нестационарного квантово- механического подхода. Экзотические ядра являются предметом интенсивного экспериментального исследования. Теоретические исследования кулоновского развала гало ядер актуальны для интерпретации и планирования экспериментов по изучению легких ядер на радиоактивных пучках. Исследования с пучками радиоактивных ядер открыли новые перспективы в изучении структуры атомного ядра и нашли широкие приложения в других областях физики, включая ядерную астрофизику. Гало ядра являются одним из наиболее интенсивно исследуемых объектов в современной малонуклонной ядерной физике. Характерной особенностью физики ядер с гало является тесная взаимосвязь механизма ядерной реакции и структуры.

Развал является одним из важных инструментов для изучения свойств гало ядер. В этих реакциях, информация, поступающая от диссоциации снаряда на фрагменты может быть использована, чтобы сделать вывод о свойствах гало части волновой функции. С хорошим приближением, развал гало ядра можно рассматривать как переход от связанного состояния двух (трех) частиц к континууму, в связи с изменяющимся кулоновским полем.

В данной работе расчитаны энергетические уровни гало ядра ^{11}Be , с учетом влияния внешнего магнитного поля, т.е. вычислено расщепление энергетических уровней численным и аналитическим методами с использованием двух разных потенциалов:в форме Вудс-Саксона и Гаусса. Ядро ^{11}Be, имеющее как нейтронное гало, состоящий из кора ^{10}Be и одного нейтрона. Эта работа является начальным этапом работы по исследованию развала гало ядер в кванто-механическом подходе.

Ключевые слова: гало ядро, кулоновский развал, сечение развала, экзотические состояния ядер, стационарное уравнение Шредингера, энергетический спектр, ядерный потенциал.

Введение. Впервые ядра с нейтронным гало были обнаружены в 1985 году Танихатой и др. [1,2], где такие экзотические системы плотно связаны с кором ядра и окружены диффузным ядерным облаком. Эти системы были обнаружены в основных состояниях (g.s.) некоторых легких, нейтроноизбыточных радиоактивных ядер, расположенных вблизи границы нейтронной стабильности [3]. Ранее считалось, что гало может образовываться только в радиоактивных ядрах, расположенных вблизи границ нуклонной стабильности. Однако еще в конце 50-х гг. прошлого столетия, задолго до открытия гало, Базь фактически предсказал [4] возможность его появления даже в стабильных ядрах вблизи порогов эмиссии нейтрона или протона.В частности, в работе [5] было показано, что возбужденное состояние 3.09 (1/2-) МэВ стабильного ядра ^{13}C может иметь структуру гало с увеличенным радиусом.

Кулоновский развал является одним из основных инструментов для изучения гало ядра. Сечение развала содержит полезную информацию о структуре гало. Таким образом, эта тема является предметом интенсивных экспериментальных и теоретических исследований. Среди гало ядер, ядро ^{11}Be имеет особое значение, так как относительная простота его структуры позволяет более точные теоретические исследования. В самом деле, связанные состояния ядра ^{11}Be можно достаточно хорошо описать как ядро ^{10}Be и слабосвязанный нейтрон. С хорошим приближением, распад можно рассматривать как переход от двухчастичного связанного состояния к континууму из за изменяющегося кулоновского поля в процессе столкновения ядер с мишенью [6].

Нейтронное гало - эффект, обусловленный наличием слабо связанных состояний нейтронов, расположенных вблизи континуума. Малая величина энергии связи нейтрона (или группы нейтронов) и короткодействующий характер ядерных сил приводят к туннелированию нейтронов во внешнюю периферийную область на большие расстояния откора ядра. При этом плотность распределения периферийных нейтронов существенно меньше плотности распределения нейтронов внутри кора [7].

Среди нейтронных гало ядер, особый интерес представляет ядро ^{11}Be. В простейшем приближении его можно рассматривать как двухчастичную систему, состоящую изкора ^{10}Be и слабо связанного нейтрона. Гало-ядро достаточно хорошо описывается волновой функцией, являющейся произведением волновых функций кора и внешнего гало. Целый ряд экспериментальных фактов подтверждает, что нуклоны, формирующие ядерное гало слабо влияют на кор ядра [6]. Наиболее известные ядра, имеющие структуру однонейтронного гало, это ^{11}Be, ^{11}Li, ^{17}C, ^{19}Cи т.д[8].Они также имеют малые энергии связи, аномально большие размеры, узкие импульсные распределения фрагментов после развала, большие сечения взаимодействия и электромагнитной диссоциации.

Практический путь изучения структуры гало - это исследование столкновений двух ядер с передачей энергии и импульса. В результате в ядерных реакциях изучаются переходные свойства ядерных систем, а именно переход из основного состояния в возбужденные [8]. Развал является одним из важных инструментов для теоретического изучения свойств гало ядер. В этих реакциях, информация, поступающая от диссоциации снаряда на фрагменты может быть использована, чтобы сделать вывод о свойствах гало части волновой функции. Кулоновский развал представляет особый интерес, потому что неопределенность в отношении предположения, что ядерное взаимодействие между снарядом и мишенью играет существенную роль. Тем не менее, для того, чтобы правильно извлечь информацию из сечений, точность описания механизма реакции должно быть установлено [9].

Характерной особенностью физики ядер с гало является тесная взаимосвязь механизма ядерной реакции и структуры ядра. Уже первичный анализ [1,2] экспериментальных данных по сечениям взаимодействия ядер с гало привел к определению больших материальных радиусов данных систем. Так как в известных ядрах с двухнейтронным гало основное состояние является единственным связанным состоянием, то развал ядер с гало в бинарных столкновениях является конечным процессом любой реакции, сопровождаемой возбуждением экзотической системы. Развитие адекватных моделей развала имеет большую практическую ценность как средство извлечения достоверной информации о структуре ядер с гало и динамике процессов взаимодействия[10].

В данной работеисследуется влияние внешнего магнитного поля на оновное состояние ядра ^{11}Be, вычисляются расщепление энергетических уровней численно и аналитически. В качестве аналитического метода выбран первый порядок теории возмущения [11].

1. Энергетический спектр гало ядра ^{11}Be. Задача сводится к решению стационарного уравнения Шредингера (УШ):

$$H\psi_{Nlm} = E_N\psi_{Nlm} \tag{1}$$

Волновую функцию можно записать в виде:

$$\psi_{Nlm}(r) = R_{Nl}(r)Y_{lm}(\theta,\varphi) \tag{2}$$

где $Y_{lm}(\theta,\varphi)$-Сферические функции.

Гамильтониан взаимодействия:

$$H_0(r) = -\frac{\hbar^2}{2\mu}\Delta + V_{cf}(r) \tag{3}$$

Тогда для радиальной волновой функции $R_{Nl}(r)$ получаем уравнение:

$$\left[-\frac{\hbar^2}{2\mu}\Delta + \frac{\hbar^2 l(l+1)}{2\mu\, r^2} + V_{cf}(r)\right]R_l(r) = E\, R_l(r) \tag{4}$$

где $\mu = \frac{m_n \cdot m_c}{M}$ - приведенная масса, m_n, m_cи M= m_n +m_c –соответственно массы нейтрона, кора и ядра ^{11}Be.

Для решения задачи (4) удобнее перейти в систему единиц, где - энергия, потенциал и масса измеряются в одних и тех же энергетических единицах – МэВ, а радиус ядра в фм, иħc=197,328 МэВ·фм. Тогда уравнение (4) запишем в виде:

$$\left[-\frac{41{,}443}{2\,(\frac{\mu}{m_n})}\frac{d^2}{dr^2} + \frac{41{,}443\; l(l+1)}{2(\frac{\mu}{m_n})\; r^2} + V_{cf}(r)\right]R_l(r) = E\, R_l(r) \tag{5}$$

Потенциал$V_{cf}(r)$состоит из центрального члена и члена спин-орбитального взаимодействия, учитывающий спин нейтрона **I** и угловой момент **L**относительного движения нейтрон-кор[6,9]

$$V_{cf}(r) = V_0(r) + \mathbf{LI}V_{LI}(r) \tag{6}$$

V_{cf} является внутренним взаимодействием между ядром и фрагментом снаряда [9]. Центральный потенциал в уравнении (6):

$$V_0(r) = -V_l f(r, R_0, a) \tag{7}$$

где Вудс-Саксоновский форм фактор:

$$f(r,R_0,a) = \left[1+\exp\left(\frac{r-R_0}{a}\right)\right]^{-1} \quad (8)$$

Спин-орбитальное взаимодействие выражается как[9]:

$$V_{LI}(r) = V_{LS}\frac{1}{r}\frac{d}{dr}\,f(r,R_0,a) \quad (9)$$

Значения параметров потенциала приведены в таблице 1, они выбраны как в работе [6].

Таблица 1- Параметры потенциалов

$V_{l=0}$ (МэВ)	$V_{l>0}$ (МэВ)	V_{LS} (МэВ фм^2)	a (фм)	R_0 (фм)
59.5	40.5	32.8	0.6	2.669

Здесь V_l- глубина потенциала Вудса-Саксона, a- диффузность,R_0- радиус ядра ^{11}Be (R_0= 1.2 $A^{1/3}$фм). Стандартное значение V_{LS} используется для глубины потенциала *ls* для ядра p-оболочки[1].

РешениеУШ (5) будем искать при граничных условиях используя численные методы обратной итерации [12], конечных-разности [13] и метод прогонки [12].

$$\begin{Bmatrix} R_{Nl}(r) \to const, r \to 0 \\ R_{Nl}(r) \to 0, r \to \infty \end{Bmatrix} \quad (10)$$

Метод обратной итерации характеризутся достаточно быстрой сходимостью к решению. Точность результата необходимо проверять по невязке. Точность вычислительной схемы равна $\Delta_i = \left|E^{(i)} - E^{(i-1)}\right| < 10^{-6}$. В уравнении производную второго порядка можно упростить для вычислителной схемы используя конечно-разностную аппроксимацию, подробно описанный в работе [7]. Вводится радиальная сетка по r_jна интервале r∈ $[0, r_m]$, для удобства ввели обозначение $R(r_j)=R_j$. С помощью прогонки находится волновая функция для первой итерации, затем проверяем нормировку. Таким образом находим энергетический уровень. Отрицательные энергетические состояния нормированы и описывают либо физические связанные состояния ^{11}Be или состояния, запрещенные принципом Паули [9].

1.1Численные методы решения стационарного уравнения Шредингера.

1.1.1Метод обратной итерации в подпространстве.Стационарное уравнение Шредингера (радиальная часть) решается методом обратной итерации [12]. Схема решения выглядит следующим образом:

$$\begin{cases} \hat{A}\vec{R} = E\vec{R} \\ (\widehat{A} - \hat{I}E^{(0)})\,\vec{R}^{(i)} = \vec{R}^{(i-1)} \\ E^{(i)} = E^{(0)} + \frac{\mathbf{1}}{\hat{R}^{(i)},\hat{R}^{(i-1)}} \end{cases}, i = \overline{1, \imath_{max}} \quad (11)$$

где $E^{(0)}$- начальное приближение для энергии,*i*- число итерации,$\hat{R}^{(0)}$ – начальный вектор, а вычисляемый конечный вектор $\hat{R}^{(i)}$ нормируется на каждой итерации $\hat{R}(r) = \widehat{\varphi}^{(\imath_{max})}$.

Преимущество данного метода в том, что конечный ответ не будет зависеть от выбора начального приближения, так как ответ быстро сходится. Тем не менее, точность результата необходимо проверять по невязке.

Из уравнения (11) можем найти, что точность вычислительной схемы равна

$$\Delta_i = \left|E^{(i)} - E^{(i-1)}\right| < 10^{-6}(12)$$

Или можно найти невязку$\delta_i < 10^{-6}$:

$$\widehat{(A} - \hat{I}E^{(i)})\, R^{(i)} = \delta_i \tag{13}$$

1.1.2 Метод прогонки. РешениеУШ (5)будем искать в виде (11) при граничных условиях:

$$\begin{Bmatrix} R_{Nl}(r) \to const, r \to 0 \\ R_{Nl}(r) \to 0, r \to \infty \end{Bmatrix} \tag{14}$$

В уравнении есть дифференциал второго порядка, который можно упростить для вычислительной схемы используя конечно-разностный метод, подробно описанный в работе [13]:

$$\frac{d^2}{dr^2}\left(R_j^{(1)}\right) = \frac{R_{j+1}^{(1)} - 2R_j^{(1)} + R_{j-1}^{(1)}}{h^2} \tag{15}$$

Здесь введена радиальная сетка по r_j, где h- шаг по сетке r_j, для удобства ввели обозначение $R(r_j)=R_j$.

Уравнение Шредингерапереходит к следующему виду

$$\hat{c}_j \vec{R}_{j+1}^{(1)} + \hat{d}_j \vec{R}_j^{(1)} + \hat{e}_j \vec{R}_{j-1}^{(1)} = \vec{R}_j^{(0)} \tag{16}$$

Видно, что уравнение (16) состоит из трёхдиагональной матрицы. Решение будем искать в следующем виде, используя метод прогонки [12]:

$$\overline{\Psi}_j = \alpha_j \overline{\Psi}_{j+1} + \beta_j$$

$$\overline{\Psi}_{j-1} = \alpha_{j-1} \overline{\Psi}_j + \beta_{j-1} \tag{17}$$

Подставляя$\bar{R}_{j-1} = \alpha_{j-1}\overline{R}_j + \beta_{j-1}$ в уравнение (16) находим, что

$$\bar{R}_j = \alpha_j{}' \overline{R}_{j+1} + \beta_j{}'$$

где коэффициенты:

$$\alpha_j{}' = -\left(\hat{d}_j + \alpha_{j-1}\hat{e}_j\right)^{-1} \cdot \hat{c}_j$$

$$\beta_j{}' = \left(\hat{d}_j + \alpha_{j-1}\hat{e}_j\right)^{-1} (\vec{R}_j^{(0)} - \beta_{j-1} \cdot \hat{e}_j) \tag{18}$$

С помощью этой схемы сначала находим коэффициенты $\alpha_j{}'\, и\, \beta_j{}'$ (прямая прогонка), затем радиальную волновую функцию $\vec{R}_j^{(1)}$ с помощью обратной прогонки. Далее проверяем нормировку. Таким образом находится волновая функция для первой итерации. Дальше как описано выше находим энергетический уровень. Отрицательные энергетические состояния нормированы и описывают либо физические связанные состояния снаряда или состояния, запрещенные принципом Паули [9].

1.2 Результаты: энергетический спектр ^{11}Be. Применяя данные численные методы, в данной работе в качестве тестовой программы были воспроизведены энергетические уровни ядра ^{11}Be для потенциала Вудс-Саксона как в работах [6,9]. Ядро ^{11}Be рассматривается как нейтронное гало, состоящий из кора ^{10}Be и одного нейтрона [6,9]. В результате были получены энергетические уровни для основного и первого возбужденного состояния. Эти данные приведены в таблице 2 и сравниваются с результатами работы[9].

Таблица 2 - Энергии основного и возбужденного состояния ^{11}Be

J^{π}	l	$E_{эксп.}$(МэВ) [14]	$E_{теор.}$(МэВ) [9]	$E_{теор.}$(МэВ) (данная работа)
$\frac{1}{2}^{+}$	0	-0.503	-0.5013	-0.5013
$\frac{1}{2}^{-}$	1	-0.183	-0.1844	-0.1844

Как уже было изложено выше, для конечно-разностной аппроксимации уравнения второго порядка по отношению к радиальной переменной r была использована сетка на интервале $r \in [0, r_m]$, где r_m=800фм для основного и первого возбужденного состояния [9]. Сходимость вычислительной схемы при $\Delta r \to 0$ представлены в таблице 3, где N_r – число точек, Δr - шаг по радиальной сетке, E – энергия связанного состояния.

Таблица 3- Сходимость вычислительной схемы на однородной радиальной сетке

N_r	Δr	E, l=0	N_r	Δr	E, l=1
2000	0.4	-0.501318	2000	0.4	-0.184423
4000	0.2	-0.780709	4000	0.2	-0.1883722
8000	0.1	-0.845679	8000	0.1	-0.1903396
16000	0.05	-0.861629	16000	0.05	-0.1913216

2. Расщепление уровней энергии ^{11}Be за счет влияния внешнего магнитного поля (Зеемановское расщепление).

В данной главе изучим влияние внешнего магнитного поля на гало состояние ядра ^{11}Be, т.е. вычислим расщепление энергетических уровней численным методом и сравним численно полученные результаты с аналитическим решением. В качестве аналитического метода выбрали первый порядок теории возмущения [11].

Под влиянием внешнего магнитного поля магнитные моменты ядер ориентируются определенным образом и появляется возможность наблюдать переходы между ядерными энергетическими уровнями, связанными с этими разными ориентациями: переходы, происходящие под действием излучения определенной частоты. Квантование энергетических уровней ядра является прямым следствием квантовой природы углового момента ядра, принимающего 2I + 1 значений. Спиновое квантовое число (спин) I может принимать любое значение, кратное ½. Расщепление уровней энергии в магнитном поле можно назвать ядерным зеемановским расщеплением, так как оно аналогично расщеплению электронных уровней в магнитном поле (эффект Зеемана) [15].

В ядерной спектроскопии широко применяется метод ядерного магнитного резонанса (ЯМР), основанного на эффекте Зеемана. В настоящее время трудно указать такую область естественных наук, где бы в той или иной степени не использовался ЯМР. Методы спектроскопии ЯМР активно применяются в химии, молекулярной физике, биологии, агрономии, медицине, при изучении природных образований, и т.д. Разработаны и выпускаются установки для исследования всего тела человека методами магнитного резонанса (методами ЯМР-томографии)[16].

Запишем радиальное уравнение Шредингера с добавлением внешнего магнитного поля ΔV_{μ}:

$$\left[\frac{\hbar^2}{2m}\frac{d^2}{dr^2} + \frac{\hbar^2}{2mr^2}\frac{l(l+1)}{} + V(r) + \Delta V_{\mu}\right] R_l(r) = E R_l(r) \qquad (19)$$

Перезапишем уравнение споправкой на систему единиц, (где энергия измерятеся в МэВ, а координата в фм) :

$$\left[\frac{\hbar^2}{2mr_0{}^2E_0}\frac{d^2}{dr'^2}+\frac{\hbar^2 l(l+1)}{2\mu r_0{}'^2E_0}-\frac{V_0'}{1+\exp\left(\frac{r'-R}{a}\right)}+\frac{\Delta V_\mu}{E_0 r_0}\right]R_l\left(\frac{r}{r_0}\right)=\frac{E}{E_0}R_l\left(\frac{r}{r_0}\right) \tag{20}$$

$$\left[-\frac{k_1}{2}\frac{d^2}{dr^2}+\frac{k_1 l(l+1)}{2r^2}+V(r)+\Delta V_\mu\right]R_l(r)=E_l R_l(r)\ , \tag{21}$$

где добавочный потенциал ΔV_μописывает взаимодействие спина нейтрона с внешним магнитным полем, поскольку, как говорилось выше, нейтронное гало ядро ^{11}Верассматривается как система ^{10}Be+n и определяется как $\Delta V = k_2 \cdot B \cdot \mu_n \cdot \hat{S}_n$; поправочные коэффициенты на ядерную систему единицk_1 =41,443 и $k_2 = 3.15 \cdot 10^{-13}\frac{МэВ}{Gфм}$, В-напряженность магнитного поля, μ_n - магнитный момент нейтрона, $\hat{S}_n$ - проекция спина на ось.

В нашем случае спин *s*=1/2, то проекция спина на выделенное направление принимает два значения: +1/2 и – 1\2. В уравнении (21) волновую функцию $R_l(r)$необходимо заменить на спиновую волновую функцию $R_l(r) \to R_l(r) \cdot \chi_m$, где$\chi_m$ представляют собой двухкомпонентные спиноры, а спиновые операторы – матрицы размерности 2×2.

Для случая когда поле направлено по оси z:$\hat{s_z} = \pm\frac{1}{2}\begin{pmatrix}1 & 0\\ 0 & -1\end{pmatrix}$.

В представлении $|s\ m_s\rangle$, где проекция спина на ось принимает значения$m_s = +\frac{1}{2}$, $m_s = -\frac{1}{2}$, тогда базисные векторы этого представления имеют вид [14]:

$$\chi_{\frac{1}{2},\frac{1}{2}} = \begin{pmatrix}1\\0\end{pmatrix}, \chi_{\frac{1}{2},-\frac{1}{2}} = \begin{pmatrix}0\\1\end{pmatrix}$$

Вводя спиновую волновую функцию видно, что УШ расщепляется на два уравнения, таким образом уровни энергии расщепляютсяна два:

$$E'_{lm=\frac{1}{2}} = E_l + \Delta E_{m=\frac{1}{2}}$$

$$E'_{lm=-\frac{1}{2}} = E_l + \Delta E_{m=-\frac{1}{2}} \tag{22}$$

Сдвиги уровней определяются как:

$$\Delta E_{m=\frac{1}{2}} =< R_{lm}^{(r)}|\frac{1}{2}k_2 \cdot B \cdot \mu_n|R_{lm}^{(r)} >$$

$$\Delta E_{m=-\frac{1}{2}} =< R_{lm}^{(r)}|-\frac{1}{2}k_2 \cdot B \cdot \mu_n|R_{lm}^{(r)} > \tag{23}$$

То же самое можем с легкостью вычислить когда поле направлено по оси x или y.

Далее модифицируем программу для вычисления сдвигов энергии (код написан для программы Фортран), заменяя волновую функцию на спинор и удваивается число матриц и векторов.

Стационарное УШ

$$H_0 R_l(r) = E R_l(r) \tag{24}$$

можем переписать в следующем виде:

$$\sum_{j=1}^{M} H_{ij}^{(0)} R_j = \sum_j \ \delta_{ij} E\, R_j = E R_i \tag{25}$$

Для описания ядерного взаимодействия использовали потенциал Вудс-Саксона с параметрами, приведенными в первой главе и также для проверки методики использовали потенциал формы Гаусса [14]:

$$V(r) = V_0 e^{-\left(\frac{r}{r_0}\right)^2} = V_0 e^{-gr^2} \tag{26}$$

Для l=0 глубина потенциала подобран как для потенциала Вудс-Саксона$V_0 = -59.5$ MeV, ширина потенциала$g = \frac{1}{r_0^2} = 0.117\ fm^{-2}$.

На рисунке 1 приведены потенциалы Вудс-Саксона (WS) и Гаусса (G) для основного состояния в зависимости от радиальной координаты. По графику видно, что для радиальной сетки r$\in [0, r_m]$ можно взять r_m=8фм.

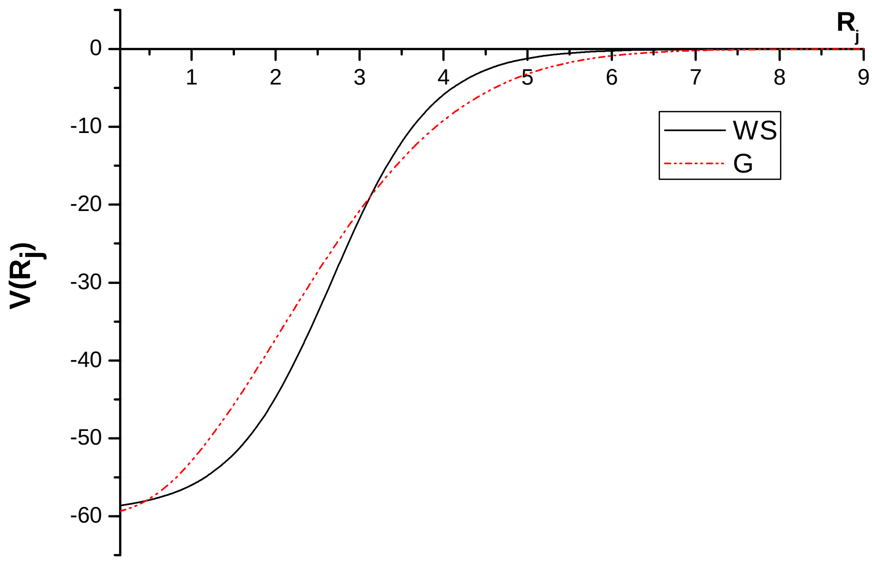


Рисунок 1 - Форма потенциала Вудс-Саксона и Гаусса для основнго состояния ^{11}Be в зависимости от радиальной переменной

Результаты для основного состояния показаны в таблице 4. Численные результаты сравниваются с аналитическим решением, в качестве аналитического взяли первый порядок теории возмущения [12].

Таблица 4 - Сдвиг энергии основного состояния ^{11}Be за счет влияния внешнего магнитного поля

R_m=8 M=200	$\Delta E_{теор.воз}(B_z)$	$\Delta E_{чис.}(B_Z)$ Гаусс	$\Delta E_{чис.}(B_Z)$ Вудс-Саксон	$\Delta E_{теор.воз}(B_z)$	$\Delta E_{чис.}(B_Z)$ Гаусс	$\Delta E_{чис.}(B_Z)$ Вудс-Саксон
B (Gauss)	m_s=+1/2 проекция спина			m_s= - 1/2 проекция спина		
0.1	0.0003	0.0003	0.0003	-0.0003	-0.0003	-0.0003
1	0.0030	0.0030	0.0030	-0.0030	-0.0030	-0.0030
10	0.0300	0.0301	0.0301	-0.0300	-0.0300	-0.0300
100	0.3008	0.3008	0.3008	-0.3008	-0.3008	-0.3008
200	0.6016	0.6016	0.6016	-0.6016	-0.6016	-0.6016
300	0.9024	0.9025	0.9025	-0.9024	-0.9025	-0.9025
400	1.2033	1.2033	1.2033	-1.2033	-1.2033	-1.2033
500	1.5041	1.5041	1.5041	-1.5041	-1.5041	-1.5041
1000	3.0082	3.0082	3.0082	-3.0082	-3.0082	-3.0082
2000	6.0165	6.0165	6.0165	-6.0165	-6.0165	-6.0165

УШ с учетом возмущения запишется как:

$$(H_0 + \Delta V)R_0(r) = E_0' R_0(r) \tag{27}$$

$$E_0' = E_0 + \Delta E$$

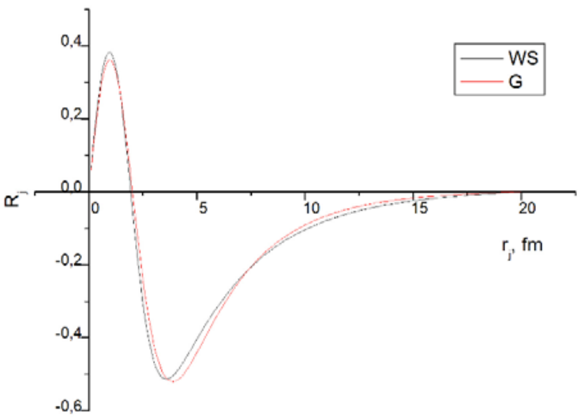
Сдвиги энергии по теории возмущения вычисляются как:

$$\Delta E_{\frac{1}{2}} = \int_0^\infty R_0(r)\Delta V_{\frac{1}{2}}(r)\, R_0(r)dr$$

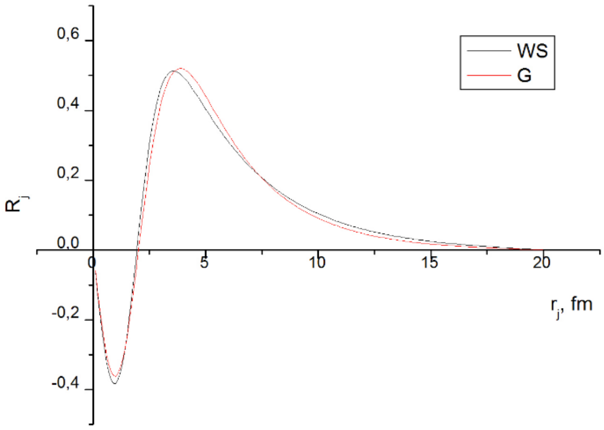
$$\Delta E_{-\frac{1}{2}} = \int_0^\infty R_0(r)\Delta V_{-\frac{1}{2}}(r)\, R_0(r)dr \qquad (28)$$

Для проверки численного результата напряженность поля меняли от 0.1 до 2000 Гаусс; видно, что результаты хорошо совпадают с аналитическими.

На рисунке 2 показаны волновые функции s-состояния ^{11}Be для проекции спина +1/2 (рис a) и -1/2 (рис b). Черным обозначены для потенциала Вудс-Саксона (WS), красным – Гаусса (G). При изменении магнитного поля волновые функции не меняются.



a)



b)

Рисунок 2- a) Радиальная волновая функция когда спин направлен вверх (+1/2) и b) когда спин направлен вниз (-1/2)

Заключение.

Применяя численные методы, в данной работе в качестве тестовой программы были воспроизведены энергетические уровни ядра ^{11}Вес использованием потенциала Вудс-Саксона для описания ядерного взаимодействия как в работах [6,9]. Ядро ^{11}Ве рассматривается как нейтронное гало, состоящий из кора ^{10}Ве и одного нейтрона [6,9].

Также были рассчитаны сдвиги уровней энергии за счет влияния магнитного поля, с использованием двух разныхпотенциалов: формы Вудс-Саксона и Гауссом. Численные результаты совпадают с аналитическим решением, в качестве аналитического выбран первый порядок теории возмущения.

Это работа является начальным этапом работы по исследованию развала гало ядер в квантово-механическом подходе. Планируется детальное исследование влияние внешнего поля на развал гало ядра, применяя численную методику решения нестационарного УШ.

Авторы выражают благодарность профессору В.С. Мележику за постановку задачи и связанные с ней дискуссии.

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МАЗМҰНЫ

Сарсембаева А.Т., Сарсембай А.Т., Мягмаржав О. 2017 жылғы 10 қыркүйекте тіркелген күн жарқылын статистикалық талдау (ағылшын тілінде)........ 5
Сарсембаева А.Т., Сарсембай А.Т., Турлыбекова Г.К., Суттикарн С. 2017 жылдың 10-20 сәуір аралығындағы күн жарқылының бақылауы (ағлшын тілінде)........ 9
Валиолда Д.С., Жаугашева С.А., Джансейтов Д.М., Жусупова Н.К. [11]Be нейтрондық гало ядросын сыртқы өріс әсерін есепке алумен зерттеу (ағылшын тілінде)........ 12
Алексеева Л.А. Серпімді кеңістік үшін беттік жүктеме қозғалысының дыбысқа дейінгі жылдамдығы кезіндегі шеттік есеп (ағылшын тілінде)........21
Жатканбаев А.А. Қауіпсіз стеганография құрылымы Диниц ең үлкен ағын алгоритміне үшін негізделген (ағылшын тілінде)........31
*Сейтмұратов А.Ж., Мәделханова Ә.Ж., Парменова М.Ж., Қанибайқызы Қ.*Тұрақты ядролы интегро-дифференциалдық теңдеулер (ағылшын тілінде)........37
Онгарбаева Д., Смагулова Л.А., Нұрмұханбетов С.М., Исаева Г.Б. MYSQL деректер қорын басқару мен оны қолданып клиент-серверлік ақпараттық жүйені өңдеу этаптары (ағылшын тілінде)........ 46
Сейтмұратов А., Медеубаев Н., Ешмұрат Г., Күдебаева Г. Қозғалмалы жүктеменің әсерінен пайда болатын, серпімді қабаттың тебеліс есебінің жуық шешімі (ағылшын тілінде)........ 54
Тәтенов А.М., Жүнісбекова А.С. Геометриялық оптика құбылыстарының математикалық байланыстар алгоритмін Flash-CC, Java script-,бағдарлау орталарында интербелсенді виртуалдау (ағылшын тілінде)........ 61
Төленов Қ.С., Дәуітбек Д. Коммутативті емес $H_E(A, \ell_\infty)$ кеңістігінің толықтығы (ағылшын тілінде)........ 66

* * *

Валиолда Д.С., Жаугашева С.А., Джансейтов Д.М., Жусупова Н.К. [11]Be нейтрондық гало ядросын сыртқы өріс әсерін есепке алумен зерттеу (орыс тілінде)........ 75

СОДЕРЖАНИЕ

Сарсембаева А.Т., Сарсембай А.Т., Мягмаржав О. Статистический анализ солнечных вспышек, зарегистрированных 10 сентября 2017 года (на английском языке)........ 5

Сарсембаева А.Т., Сарсембай А.Т., Турлыбекова Г.К., Суттикарн С. Мониторинг солнечных вспышек в период 10-20 апреля 2017 года (на английском языке)........ 9

Валиолда Д.С., Жаугашева С.А., Джансейтов Д.М., Жусупова Н.К. Изучение нейтронного гало ядра ^{11}Be с учетом влияния внешнего поля (на английском языке)........ 12

Алексеева Л.А. Краевая задача для упругого полупространства при дозвуковых скоростях движения поверхностной нагрузки (на английском языке)........ 21

ЖатқанбаевА.А. Использование алгоритмов ФлойдаУоршелла, Беллмана-Форда для добавления перестановок шума блочных шифров для усиления криптостойкости (на английском языке)........ 31

*Сейтмуратов А.Ж., Маделханова А.Ж., Канибайкызы К.*Интегро-дифференциальные уравнения с регулярными ядрами (на английском языке)........ 37

Онгарбаева А.Д., Смагулова Л.А., Нурмуханбетов С.М., Исаева Г.Б. Управление базами данных MYSQL и этапы разработки клиент-серверной информационной системы с использованием MYSQL (на английском языке)....... 46

Сейтмуратов А., Медеубаев Н., Ешмурат Г., Кудебаева Г. Приближенное решение задачи о колебании упругого слоя, подвергающегося воздействию подвижной нагрузки (на английском языке)........ 54

Татенов А.М., Жунисбекова А.С. Интерактивная виртуализация в среде Flash-CC, Java script- алгоритмов математических связей явлении геометрической оптики (на английском языке)........ 61

Туленов К.С., Дауитбек Д. Полнота некоммутативного пространство $H_E(\mathrm{A}, \ell_\infty)$ (на английском языке)........ 66

* * *

Валиолда Д.С., Жаугашева С.А., Джансейтов Д.М., Жусупова Н.К. Изучение нейтронного гало ядра ^{11}Be с учетом влияния внешнего поля (на русском языке)........ 75

CONTENTS

Sarsembayeva A.T., Sarsembay A.T., Myagmarjav O. statistical analysis of x-ray solar flare registered on september 10, 2017 (in English)........ 5
Sarsembayeva A.T., Sarsembay A.T., Turlybekova G.K., Suttikarn S. Solar activity monitoring for the period april 10-20, 2017 (in English)........ 9
Valiolda D.S., Zhaugasheva S.A., Janseitov D.M., Zhussupova N.K. The study of the neutron halo of the ^{11}Be nucleus taking into account the influence of an external field (in English)........ 12
Alexeyeva L.A. Boundary value problem for elastic half-space by subsonic velocities of surface transport loads moving (in English)........ 21
Zhatkanbayev A.A. Appliance of floyd warshall, bellman-ford algorithms for adding noise permutations of block ciphers for cryptographic endurance enhancement (in English)........ 31
Seitmuratov A.Zh., Madelkhanova A.Zh., Parmenova M.Zh., Kanibaikyzy K. Integro-differential equations with regular kernels (in English)........ 37
Ongarbayeva A., Smagulova L., Nurmukhanbetov S., Issayeva G. Managing the MYSQL database and the stages of development of client server information system using MYSQL (in English) 46
Seitmuratov A., Medeubaev N., Yeshmurat G., Kudebayeva G. Approximate solution of the an elastic layer vibration task being exposed of moving load (in English) 54
Tatenov A.M., Zhunisbekova A.S. Interactive virtualization in the environment of Flash-CC, Java script of algorithms of mathematical communications the phenomenon of geometrical optics (in English) 61
Tulenov K.S., Dauitbek D. The completeness of the noncommutative $H_E(\mathcal{A}, \ell_\infty)$ space (in English) 66

* * *

Valiolda D.S., Zhaugasheva S.A., Janseitov D.M., Zhussupova N.K. The study of the neutron halo of the ^{11}Be nucleus taking into account the influence of an external field (in Russian)........75

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