

<http://road.issn.org/issn/2518-1726>

ISSN 1991-346X

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН

NEWS

OF THE NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN

**ФИЗИКА-МАТЕМАТИКА
СЕРИЯСЫ**



СЕРИЯ

ФИЗИКО-МАТЕМАТИЧЕСКАЯ



**PHYSICO-MATHEMATICAL
SERIES**

5 (309)

**ҚЫРКҮЙЕК – ҚАЗАН 2016 ж.
СЕНТЯБРЬ – ОКТЯБРЬ 2016 г.
SEPTEMBER – OCTOBER 2016**

1963 ЖЫЛДЫҢ ҚАҢТАР АЙЫНАН ШЫҒА БАСТАҒАН
ИЗДАЕТСЯ С ЯНВАРЯ 1963 ГОДА
PUBLISHED SINCE JANUARY 1963

ЖЫЛЫНА 6 РЕТ ШЫҒАДЫ
ВЫХОДИТ 6 РАЗ В ГОД
PUBLISHED 6 TIMES A YEAR

АЛМАТЫ, ҚР ҰҒА
АЛМАТЫ, НАН РК
ALMATY, NAS RK

ҚР ҰҒА ХАБАРЛАРЫ. ФИЗИКА-МАТЕМАТИКА СЕРИЯСЫ

Бас редакторы
ф.-м.ғ.д., проф., ҚР ҰҒА академигі **Ғ.М. Мұтанов**

Р е д а к ц и я а л қ а с ы:

Жұмаділдаев А.С. проф., академик (Қазақстан)
Кальменов Т.Ш. проф., академик (Қазақстан)
Жантаев Ж.Ш. проф., корр.-мүшесі (Қазақстан)
Өмірбаев У.У. проф. корр.-мүшесі (Қазақстан)
Жүсіпов М.А. проф. (Қазақстан)
Жұмабаев Д.С. проф. (Қазақстан)
Асанова А.Т. проф. (Қазақстан)
Бошкаев К.А. PhD докторы (Қазақстан)
Сұраған Д. PhD докторы (Қазақстан)
Quevedo Hernando проф. (Мексика),
Джунушалиев В.Д. проф. (Қырғыстан)
Вишневский И.Н. проф., академик (Украина)
Ковалев А.М. проф., академик (Украина)
Михалевич А.А. проф., академик (Белорус)
Пашаев А. проф., академик (Әзірбайжан)
Такибаев Н.Ж. проф., академик (Қазақстан), бас ред. орынбасары
Тигиняну И. проф., академик (Молдова)

ИЗВЕСТИЯ НАН РК. СЕРИЯ ФИЗИКО-МАТЕМАТИЧЕСКАЯ

Главный редактор
д.ф.-м.н., проф. академик НАН РК **Г.М. Мутанов**

Редакционная коллегия:

Джумадильдаев А.С. проф., академик (Казахстан)
Кальменов Т.Ш. проф., академик (Казахстан)
Жантаев Ж.Ш. проф., чл.-корр. (Казахстан)
Умирбаев У.У. проф. чл.-корр. (Казахстан)
Жусупов М.А. проф. (Казахстан)
Джумабаев Д.С. проф. (Казахстан)
Асанова А.Т. проф. (Казахстан)
Бошкаев К.А. доктор PhD (Казахстан)
Сураган Д. доктор PhD (Казахстан)
Quevedo Hernando проф. (Мексика),
Джунушалиев В.Д. проф. (Кыргызстан)
Вишневский И.Н. проф., академик (Украина)
Ковалев А.М. проф., академик (Украина)
Михалевич А.А. проф., академик (Беларусь)
Пашаев А. проф., академик (Азербайджан)
Такибаев Н.Ж. проф., академик (Казахстан), зам. гл. ред.
Тигиняну И. проф., академик (Молдова)

«Известия НАН РК. Серия физико-математическая». ISSN 1991-346X

<http://road.issn.org/issn/2518-1726>

Собственник: РОО «Национальная академия наук Республики Казахстан» (г. Алматы)

Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан №5543-Ж, выданное 01.06.2006 г.

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18,
[www.nauka-nanrk.kz / physics-mathematics.kz](http://www.nauka-nanrk.kz/physics-mathematics.kz)

© Национальная академия наук Республики Казахстан, 2016

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

**NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC
OF KAZAKHSTAN. SERIES OF PHYSICS AND MATHEMATICS**

Editor in chief

doctor of physics and mathematics, professor, academician of NAS RK **G.M. Mutanov**

Editorial board:

Dzhumadildayev A.S. prof., academician (Kazakhstan)
Kalmenov T.Sh. prof., academician (Kazakhstan)
Zhantayev Zh.Sh. prof., corr. member. (Kazakhstan)
Umirbayev U.U. prof. corr. member. (Kazakhstan)
Zhusupov M.A. prof. (Kazakhstan)
Dzhumabayev D.S. prof. (Kazakhstan)
Asanova A.T. prof. (Kazakhstan)
Boshkayev K.A. PhD (Kazakhstan)
Suragan D. PhD (Kazakhstan)
Quevedo Hernando prof. (Mexico),
Dzhunushaliyev V.D. prof. (Kyrgyzstan)
Vishnevskiy I.N. prof., academician (Ukraine)
Kovalev A.M. prof., academician (Ukraine)
Mikhalevich A.A. prof., academician (Belarus)
Pashayev A. prof., academician (Azerbaijan)
Takibayev N.Zh. prof., academician (Kazakhstan), deputy editor in chief.
Tiginyanu I. prof., academician (Moldova)

News of the National Academy of Sciences of the Republic of Kazakhstan. Physical-mathematical series.
ISSN 1991-346X

<http://road.issn.org/issn/2518-1726>

Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)

The certificate of registration of a periodic printed publication in the Committee of information and archives of the Ministry of culture and information of the Republic of Kazakhstan N 5543-Ж, issued 01.06.2006

Periodicity: 6 times a year

Circulation: 300 copies

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18,
www.nauka-nanrk.kz / physics-mathematics.kz

© National Academy of Sciences of the Republic of Kazakhstan, 2016

Address of printing house: ST "Aruna", 75, Muratbayev str, Almaty

NEWS

OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
PHYSICO-MATHEMATICAL SERIES

ISSN 1991-346X

Volume 5, Number 309 (2016), 160 – 167

UDK 517.927

B.K. Kaldybekova¹, G. V. Reshetova²

¹Kazakh-British Technical University, Almaty, the Republic of Kazakhstan, bekrat_87@inbox.ru

²Institute of Computational Mathematics and Mathematical Geophysics SB RAS, Novosibirsk, Russia,
kgv@nmsf.ssc.ru

NUMERICAL RESULTS OF SPECIAL GRID OF STRINGS

Abstract. In this paper some numerical results about natural oscillations of a special grid of strings are considered. The problem of a string of natural frequencies of such grid is reduced to the Sturm-Liouville problem on the grid. The main result of the work is given in programming language Matlab. The finite-difference method is used to study the problem of special grid of string.

Keywords: string, vertex, edges, node, eigenvalue, eigenvector.

Introduction. In this paper we give some numerical results about natural oscillations of a special grid of strings (see [1], [2]). The system consists of a finite number of strings attached to each other as it is shown on the Figure 1.

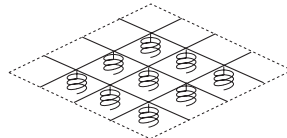


Figure 1 – A grid of strings

We assume our system consists of a finite number of strings, attached to each other in the form of a grid having the square cells. Each “internal” node is supposed to be attached to the springs and (a point of the adjacency of four strings) could move in the direction orthogonal to the coordinate plane O_{xy} (this plane gives a geometric representation of the plane, containing an initial configuration at rest). The grid experiences a resistance of these springs during movement. The nodes of the grid lying on the boundary (the boundary is marked by the dotted line on the Figure 1) are supposed to be fixed.

We will show that that under some assumptions about mass distribution, a tension of each string and elasticity coefficients of the springs the initial part of the spectrum of frequency of natural oscillations of the grid is close to analogues part of frequencies of some membrane, if the mesh (the size of square cells enclosed by strings) is small enough.

Moreover the corresponding modes of oscillations of the grid and the membrane are also close to each other.

Mathematical model. We assume that a mass distribution along each string is given by the function

$$\rho = \frac{h}{2}, \quad (1)$$

where h is the length of the string; we assume the grid stretched over the unit square (see Figure 1) and the length h equals $1/n$ (n is number of strings in a horizontal or vertical chain of string between the dotted lines).

The grid is stretched so that the tension of each string equals

$$T_h = h. \quad (2)$$

The elasticity coefficient of each string equals to

$$k_h = h^2. \quad (3)$$

To reformulate in mathematical terms a problem of natural oscillations, we interpret a grid as a graph G_h with vertical and horizontal edges e (former strings) adjacent to each other in vertices $v = (ih, jh)$, ($0 \leq i, j \leq n$) (former nodes). Each edge may be parameterize by $t \in [0; h]$, i.e. we use a natural parameter – the arc length. We assume the horizontal edges are oriented from the left to the right, while the vertical edges oriented from the bottom to the top. Besides, we assume that the parameterization of each is agreed with the orientation. Under these conventions a problem of natural oscillations of the grid could easily be converted into the following boundary value problems (an analog of Sturm – Liouville’s problem, see [3],[4]):

$$u_e'' + \frac{\lambda}{2} u_e = 0, \quad e \in E \quad (4)$$

$$\sum_{e \succ v} u_e'(v) - hu(v) = 0, \quad v \in V_0 \quad (5)$$

$$u_e(v) = u(v), \quad \text{for } e \succ v, \quad v \in V_0 \quad (6)$$

$$u(v) = 0, \quad v \in \partial G_h. \quad (7)$$

Here u_e stands for a restriction of the function $u: G_h \rightarrow R$ on the edge e . In (4) a differentiation relates to the natural parameter; here an orientation of the edge does not assume $u_e'(v)$ means the derivative in the internal direction of the edge e (from the vertex v into the interior of the edge e). A notation V_0 stands for the set of internal vertices.

Under the assumptions taken above, our mechanical system is similar (an exact meaning of the word “similar” will be discussed later in this section) to a membrane, which natural oscillations are modeled by the following boundary value problem:

$$\begin{cases} \Delta u - u + \lambda u = 0 & (8) \end{cases}$$

$$\begin{cases} u|_{\partial Q} = 0, & (9) \end{cases}$$

where $Q = [0, 1] \times [0, 1]$.

In fact, one can easily find, that the total mass of the grid of string approximately equals to 1 for h small enough (see our assumption (1)), and the mass of the membrane, described by (8),(9), equals to 1 too. One can also see that the assumption (2) about the tensions of strings makes the grid similar to the membrane in the sense of similarity between elasticities of this two mechanical systems. In fact, the region, “covered” by a grid may be tasseled into squares with side lengths h , centered at the vertices of the graph. Each side of each square is intersected by the unique edge of the graph. If we distribute the tension of corresponding string (which equals h by magnitude and orthogonal to the side of square) along the side, we will obtain a set of squares stretched as a the cells of membrane (8),(9). Similar arguments show that the last mechanical assumption (3) about the elastic resistance of the springs, applied to the grid at its vertices, is equivalent to the exterior elastic resistance applied to the membrane (the term $-u$ in the equation (8)).

Finite-difference method. We reduce the problem (4)-(7) to the system of linear equations using finite difference method (see[5], [6], [7]). Let us give k vertical and k horizontal lines and $k+1$ edge on each line. The problem (4)-(7) looks like as following:

$$u''_{i,j}(x) + \frac{\lambda}{2} u_{i,j}(x) = 0, \quad w''_{j,i}(y) + \frac{\lambda}{2} w_{j,i}(y) = 0, \quad x, y \in G_h, \quad i = \overline{1, k+1}, \quad j = \overline{1, k}, \quad (4^*)$$

$$u'_{i,j}(v) + u'_{i+1,j}(v) + w'_{i,j}(v) + w'_{i,j+1}(v) - hu(v) = 0, \quad v \in V_0, \quad i = \overline{1, k}, \quad j = \overline{1, k}, \quad (5^*)$$

$$u_{i,j}(v) = u_{i+1,j}(v) = w_{i,j}(v) = w_{i,j+1}(v), \quad v \in V_0, \quad i = \overline{1, k}, \quad j = \overline{1, k}, \quad (6^*)$$

$$u_{1,i}(v) = 0, \quad u_{k+1,i}(v) = 0, \quad w_{i,1}(v) = 0, \quad w_{i,k+1}(v) = 0, \quad v \in \partial G_h, \quad i = \overline{1, k} \quad (7^*)$$

where $u_{i,j}(x)$ – the functions on horizontal edges, $w_{i,j}(y)$ – the functions on vertical edges.

First we replace the square grid of graph G_h to a finite set of points of this grid. For this purpose (see the Figure 2) we split each edge into n pieces by $n+1$ equidistant points.

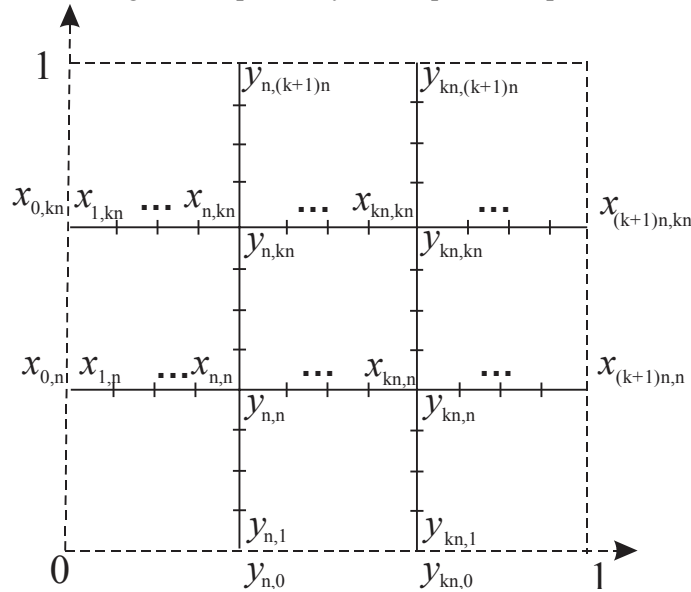


Figure 2 – Difference scheme of grid in points

Then each chain of horizontal (vertical) edges lying on and the same horizontal (vertical) line has been divided into $n \times (k+1)$ (where k is the number of horizontal (vertical) line). Let us denote the new grid by \tilde{G}_h which correspondent to the following conditions:

a) on horizontal lines

$$x_{0,n} = (0, n\tau), \quad x_{1,n} = (\tau, n\tau), \quad \dots, \quad x_{(k+1)n,n} = ((k+1)n\tau, n\tau),$$

$$x_{0,kn} = (0, kn\tau), \quad x_{1,n} = (\tau, kn\tau), \quad \dots, \quad x_{(k+1)n,n} = ((k+1)n\tau, kn\tau),$$

b) on vertical lines

$$y_{n,0} = (n\tau, 0), \quad y_{n,1} = (n\tau, \tau), \quad \dots, \quad y_{n,(k+1)n} = (n\tau, (k+1)n\tau),$$

$$y_{kn,0} = (kn\tau, 0), \quad y_{kn,1} = (kn\tau, \tau), \quad \dots, \quad y_{kn,(k+1)n} = (kn\tau, (k+1)n\tau),$$

where τ – is step of the new grid and the value of functions $u_{i,j}(x), w_{i,j}(y)$ at the point

$x_{i,j}, y_{i,j} \in \tilde{G}_h$ corresponding by $\tilde{u}_{i,j}, \tilde{w}_{i,j}$. The points $x_{i,j}, y_{i,j}$ are called nodes of grid \tilde{G}_h :

$$\tilde{G}_h = \{x_{i-1,jn} = ((i-1)\tau, jn\tau), \quad y_{jn,i-1} = (jn\tau, (i-1)\tau), \quad i = \overline{1, n(k+1)+1}, \quad j = \overline{1, k}\}$$

where

$$\tau = \frac{1}{(k+1)n}$$

The selected scheme of approximation of the partial differential can be graphically represented as following:

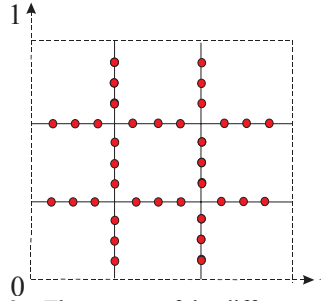


Figure 3 – The pattern of the difference scheme

In this scheme we consider only interior nodes of each edge (see Figure 3), because the condition (2*) at the interior vertices $v_{i,j} = x_{in,jn}$ ($i = \overline{1, k}, j = \overline{1, k}$) break the symmetry of the matrix of the problem (4*)-(7*). We can easily determine all values at the interior vertices $v_{i,j} = x_{in,jn}$ ($i = \overline{1, k}, j = \overline{1, k}$) of grid \tilde{G}_h by four neighbor interior nodes $x_{in-1,jn}, x_{in+1,jn}, x_{in,jn-1}, x_{in,jn+1}$:

$$u_{in,jn} = \frac{w_{in,jn-1} + w_{in,jn+1} + u_{in-1,jn} + u_{in+1,jn}}{4 + \tau h}, \quad i = \overline{1, k}, \quad j = \overline{1, k}.$$

We replace the differential operators in (6*)-(7*) in their finite difference analogues:

$$u_{in,jn} = w_{in,jn}, \quad i = \overline{1, k}, \quad j = \overline{1, k}, \tag{6**}$$

$$u_{0,in} = 0, \quad u_{(k+1)n,in} = 0, \quad w_{in,0} = 0, \quad w_{in,(k+1)n} = 0, \quad i = \overline{1, k} \tag{7**}$$

We approximate of derivatives of the system (4*) using the conditions (5**), (6**), (7**). First, we give analogue of the equation (4*) at the first and end nodes of each line

$$2 \frac{u_{2,jn} - 2u_{1,jn}}{\tau^2} + \lambda u_{1,jn} = 0, \quad 2 \frac{u_{(k+1)n-2,jn} - 2u_{(k+1)n-1,jn}}{\tau^2} + \lambda u_{(k+1)n-1,jn} = 0, \quad j = \overline{1, k},$$

$$2 \frac{w_{jn,2} - 2w_{jn,1}}{\tau^2} + \lambda w_{jn,1} = 0, \quad 2 \frac{w_{jn,(k+1)n-2} - 2w_{jn,(k+1)n-1}}{\tau^2} + \lambda w_{jn,(k+1)n-1} = 0, \quad j = \overline{1, k}.$$

As a result of the approximation of the partial derivatives corresponding finite difference we get the following system of linear algebraic equations at the interior nodes of each line, not including interior vertices on this lines:

$$\begin{aligned} 2 \frac{u_{i+1,jn} - 2u_{i,jn} + u_{i-1,jn}}{\tau^2} + \lambda u_{i,jn} = 0, \quad 2 \frac{w_{jn,i+1} - 2w_{jn,i} + w_{jn,i-1}}{\tau^2} + \lambda w_{jn,i} = 0, \\ j = \overline{1, k}, \quad i = (\mathfrak{E}-1)n + 2, \mathfrak{E}n - 2, \quad \mathfrak{E} = \overline{1, k}, \end{aligned}$$

Finally, we give approximation of (1*) (see [8]) at the neighbor nodes of interior vertices $x_{in,jn}$ using the condition (5**)

$$\begin{cases} 2 \frac{u_{in-2,jn} - 2u_{in-1,jn}}{\tau^2} + 2 \frac{u_{in-1,jn} + u_{in+1,jn} + w_{in,jn+1} + w_{in,jn-1}}{(4 + \tau h)\tau^2} + \lambda u_{in-1,jn} = 0, \quad j = \overline{1, k}, \quad i = \overline{1, k}, \\ 2 \frac{w_{in,jn-2} - 2w_{in,jn-1}}{\tau^2} + 2 \frac{w_{in,jn-1} + w_{in,jn+1} + u_{in+1,jn} + u_{in-1,jn}}{(4 + \tau h)\tau^2} + \lambda w_{in-1,jn} = 0, \quad j = \overline{1, k}, \quad i = \overline{1, k}. \end{cases}$$

Results. In this section we give some numerical results of the problem (4)-(7) and (8)-(9) by the programming language Matlab (see [9], [10], [11]). Matlab has a large number of packages, which increase efficiency of the system more times. One of such package is a PDE TOOLBOX, which intended

for solving differential equations in partial derivatives and their systems (see [12], [13]). We used package PDE TOOLBOX in the calculation of the eigenvalues and eigenfunctions of the membrane. The calculation of these problems is made on a square grid $[0,1] \times [0,1]$. It was investigated eigenvalues and eigenfunctions of special grid of string (see [14], [15], [16]), which the number of vertical (horizontal) lines equal to $k = 8$. The number of edge on each line equals to 9 and the length of each edge is $h = \frac{1}{9}$, $n=50$, thus step of the grid \tilde{G}_h equals to $\tau = 0.002$. Let us denote step of membrane by \tilde{h} . The step of membrane approximately equals to $\tilde{h} \approx 0.0257$.

In the Table 1 the eigenfunctions of a special of grid string and the eigenfunctions of some membrane is shown. One can see that the eigenfunctions of special grid of string and membrane are similar (see ([17], [18], [19])).

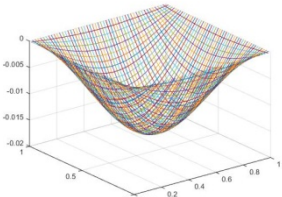
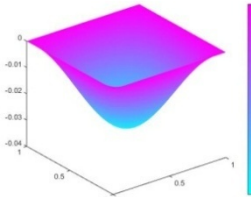
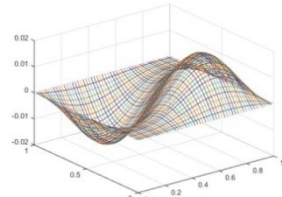
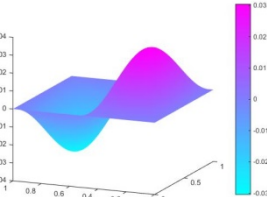
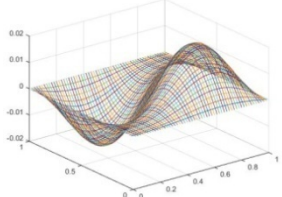
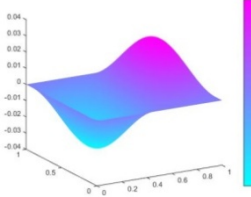
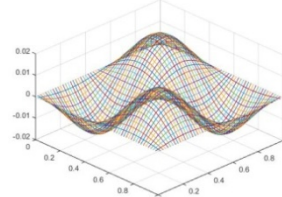
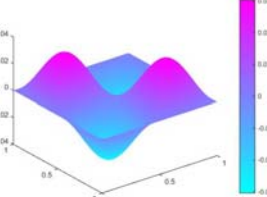
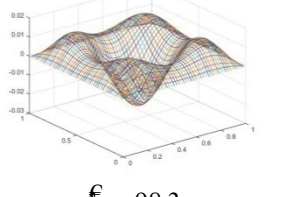
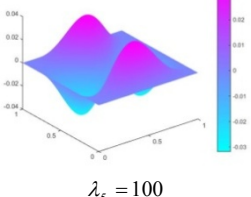
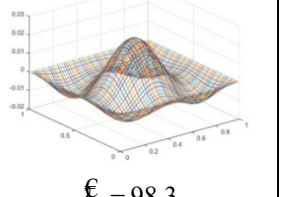
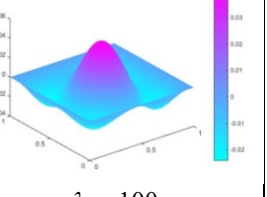
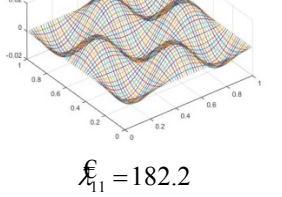
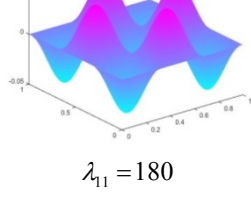
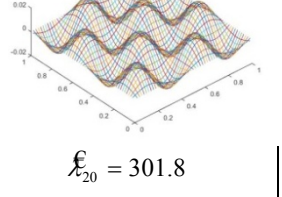
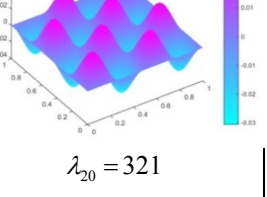
Eigenfunction of string	Eigenfunction of membrane	Eigenfunction of string	Eigenfunction of membrane
 $\xi_1 = 21.2$	 $\lambda_1 = 20.7$	 $\xi_2 = 50.9$	 $\lambda_2 = 50.5$
 $\xi_3 = 50.9$	 $\lambda_3 = 50.5$	 $\xi_4 = 81.5$	 $\lambda_4 = 80$
 $\xi_5 = 98.3$	 $\lambda_5 = 100$	 $\xi_6 = 98.3$	 $\lambda_6 = 100$
 $\xi_{11} = 182.2$	 $\lambda_{11} = 180$	 $\xi_{20} = 301.8$	 $\lambda_{20} = 321$

Table 1 – The eigenfunctions of special grid of string and some membrane. ξ_i – eigenvalue of string, λ_i – eigenvalue of membrane

In the Table 2 the results of eigenvalues of special grid of string and membrane, where $h = 0.1$, $\tau = 0.002$, $\tilde{h} = 0.0257$ is shown. The eigenvalue of special grid of string closes to eigenvalue of membrane.

№	Eigenvalue of membrane λ_i	Eigenvalue of string ξ_i
1	20.7559	21.1613052346441
2	50.4513	50.9031594257733
3	50.4529	50.9031594260744
4	80.2238	81.5835446935957
5	100.1136	98.3161096946738
6	100.1148	98.3161096957769
7	130.0003	130.582745409383
8	130.0081	130.582745409516
9	169.9894	159.902826747078
10	169.9936	159.902826748113
11	180.0268	182.280004180308
12	200.0311	194.412522103279
13	200.0921	194.412522106297
14	250.3364	230.279322042279
15	250.3607	230.279322045306
16	260.3620	249.963262489939
17	260.3923	249.963262491362
18	290.6995	267.640881097907
19	290.7233	267.640881099888
20	321.1546	301.858857023673
21	341.3851	301.858857025118
22	341.5113	323.238452409586
23	371.8041	328.159780158053
24	371.8246	328.159780158240
25	402.3908	342.491053529061
26	402.4323	342.491053530374
27	412.7390	364.930055817108
28	412.8251	364.930055819259
29	453.6041	408.809859855501
30	453.6347	408.809859855804
31	504.7279	408.809859856058
32	504.9670	408.809859856083
33	505.1312	408.809859856117
34	525.6132	408.809859856134
35	525.7821	408.809859856204
36	535.7358	408.809859856494

37	535.8112	455.184680914906
38	587.5983	455.184680916734
39	587.8342	481.005232747412
40	618.6800	481.005232749098
41	618.7805	498.329459142439
42	660.1324	498.329459143523
43	660.1881	504.437824568321
44	660.3037	531.980972499042
45	660.3657	531.980972500144
46	691.5258	579.831176750581
47	691.8229	579.831176752192
48	733.7459	606.618121773322
49	743.8976	606.618121774464
50	743.9673	638.344087858107
51	754.2927	638.344087860762
52	755.1989	702.180188253403

Table 2 – Eigenvalues of a special grid of string and some membrane. λ_i – eigenvalue of string, λ_i – eigenvalue of membrane

Conclusion. The numerical results about eigenvalues and corresponding eigenfunctions of a special grid of strings in the square $[0, 1] \times [0, 1]$ have been researched. It was shown that the eigenvalues of a special grid of strings partially close to the eigenvalues of membrane (see [20]) and the eigenfunctions are similar.

REFERENCES

- [1] Komarov A. V., Penkin O.M., and Pokornyi Yu. V., On the spectrum of a uniform network of strings // *Izv Vuzov, Mat* – 2000 – № 4, pp. 23-27.
- [2] Nicaise S., Penkin O.M., Relationship between the lower frequency spectrum of plates and networks of beams // *Math. Meth. Appl. Sci.*, – 2000 – № 23, pp. 1389-1399.
- [3] Pokorny, Yu. V.; Penkin, O. M., Pryadiev V.L. and others. *Differential equations on geometric graphs* // *Fiziko-Matematicheskaya Literatura – Moscow*, 2005 – ISBN: 5-9221-0425-X, 272 pp.
- [4] Friedman A., *Partial Differential Equations* // Holt, Rinehart and Winston – 1969.
- [5] Alexander A. Samarskii, *The theory of difference schemes* // Marcel Dekker – Inc. 270 Madison Avenue, New York, 2001 – pp. 145-290. (in English)
- [6] Godunov S.K., Riabenky V. S., *Theory of difference schemes, an introduction* // Interscience Publishers – New York, 1964 – p. 222. (in English)
- [7] Kato T., *Perturbation Theory for linear operators* // Springer – Heidelberg, 1966.
- [8] Quarteroni A., Valli A. *Numerical Approximation of Partial Differential Equations* // Springer Series in Computational Mathematics, Berlin, Volume 23, 1994. (in English)
- [9] Zolotykh N. Yu., *Using Matlab package in the scientific and educational work* // Nizhnij Novgorod, 2006 (in Russian)
- [10] Plohotnikov K. E., *Computational methods. Theory and Practice in the Matlab environment: lectures* // Gorjachaja linija – Moscow, 2009 – pp. 108-198.
- [11] D'jakonov V.P., *MATLAB. Complete guide* // DMK Press – Moscow, 2010 – p. 768.
- [12] http://geometry.karazin.ua/resources/documents/20140425101823_05e9c091f50f.pdf
- [13] *Partial Differential Equation Toolbox User's Guide* // The MathWorks, Inc. 24 Prime Park Way – Natick, 1995 – p. 284.
- [14] Zhikov V.V., Kozlov S.M., Oleinik O.A. *Homogenization of Differential Operators and Integral Functionals* // Springer Verlag, 1994 (in English)
- [15] Zhikov V.V., *Connectedness and homogenization. Examples of fractal conductivity* // *Sbornik: Mathematics*, 1996, 187:8, 1109–1147 (in Russian)
- [16] Zhikov V.V., Kozlov S.N., and Oleinik A. O., *Homogenization of Differential Operators* // Nauka – Moscow, 1993.
- [17] Szego G., *Inequalities for certain eigenvalues of a membrane of a given area* // *J. Rat. Mech. Anal.* – 1954 – № 3, pp. 342-356.

[18] Gulgazaryan G.R., Lidskii V.B., and Eskin G. I., The spectrum of the membrane system on the case of a thin shell of an arbitrary shape // Sibirsk. Mat. Zh.– 1973 – № 14 , pp. 978-986, English trans. In Siberyan Math. J. 14 (1973), pp. 681-687.

[19] Lidskii V. B. and Kharkova N. V., The spectrum of membrane equations in the case of axisymmetrical vibrations of a shell of revolution // Doklady AN SSSR – 1970 – № 194, pp. 786-789, English Translation in Sov. Phys. Dokl. № 15, 1970-71, pp. 982-984.

[20] <http://www.mathworks.com/help/pde/eigenvalue-problems.html>

Б. К.Калдыбекова¹, Г. В. Решетова¹

¹Казахстанско-Британский технический университет, Алматы, Республика Казахстан, bekzat_87@inbox.ru

²Институт вычислительной математики и математической геофизики Сибирского отделения РАН, Новосибирск, Россия

ЧИСЛЕННЫЕ РЕЗУЛЬТАТЫ СПЕЦИАЛЬНОЙ СЕТКИ ИЗ СТРУН

Аннотация. В данной работе рассматриваются некоторые численные результаты о собственных колебаний специальной сетки из струн. Задача о струне частот собственных колебаний такой сетки сводится к задаче Штурма-Лиувилля на сетки. Для изучения колебаний специальной сетки из струн используется метод конечных разностей. Основные результаты работы даются на языке программирования Matlab.

Ключевые слова: струна, вершина, ребра, узел, собственное число, собственный вектор

Б.Қ. Қалдыбекова¹, Г.В. Решетова²

¹Қазақстан-Британ техникалық университеті, Алматы, Қазақстан Республикасы;

²Есептеу математикасы және математикалық геофизика Институтының Сібір бөлімшесі, РҒА, Новосибирск, Ресей,

АРНАЙЫ ІШЕКТЕН ЖАСАЛҒАН ТОРДЫҢ САНДЫҚ НӘТИЖЕЛЕРІ

Аннотация. Бұл жұмыста ішектен жасалған арнайы тордың меншікті тербелісінің сандық нәтижелері қарастырылады. Мұндай ішектен жасалған арнайы тордың меншікті тербеліс жиілігі туралы есеп тордағы Штурм-Лиувилл есебіне келтіріледі. Ішектен жасалған арнайы тор тербелісін зерттеу барысында ақырлы-айырымдық әдіс қолданылған. Жұмыстың негізгі алынған нәтижелері Matlab программалау тілінде зерттелген.

Түйін сөздер: ішек, төбе, қабырға, түйін, меншікті мән, меншікті вектор.

МАЗМҰНЫ

Жұлдыздардың және тұмандықтардың зерттеулері

<i>Серебрянский А.В., Гайнуллина Е.Р., Халикова А.В.</i> , ТУС3215-906-1 айнымалы жұлдыз: бүгілген жаркылдың талдауы және жіктеуі.....	5
<i>Кондратьева Л.Н., Рспаев Ф.К., Аймуратов Е.К., Отебай А.Б.</i> , V725 Тау объектісінің спектрлік және фотометрлік бақылауларының нәтижелері.....	12
<i>Кондратьева Л.Н., Рспаев Ф.К., Аймуратов Е.К.</i> , M1-65 планеталық тұмандықтың айнымалылығы.....	22
<i>Павлова Л.А.</i> , Жұлдыз маңындағы құрылымдардың қалыптасуына магниттік өрістердің әсері.....	29
<i>Кокумбаева Р.И., Хруслов А.В., Кусакин А.В.</i> , GSC 3601-01531 және GSC 3601-01504 екі жаңа айнымалы жұлдыздар	35

Аспан механикасының және жұлдыздар жүйесінің мәселелері

<i>Дубовиченко С.Б., Джазаиров-Кахраманов А.В., Буркова Н.А., Ткаченко А.С.</i> , Астрофизикалық энергия кезінде радиациялық ${}^2\text{H}^3\text{He}$ басып алу	41
<i>Зулыхаров А.Т., Коньсбаев Т.К., Чечин Л.М.</i> , Қараңғы материя есебімен ғаламдар релаксацияларының уақытын бағалау.....	50

Күннің және күн жүйесі денелерінің физикасы

<i>Шестакова Л.И., Демченко Б.И.</i> , А тобы жұлдыздары дискілерінде атомдар мен иондар динамикасына бүгілген жарық қысымының әсері.....	55
<i>Демченко Б.И., Шестакова Л.И.</i> , Күн маңындағы сублимация процессінде оливин тозақ бөлшектерінің орбиталық дамуы	64
<i>Шестакова Л.И., Демченко Б.И.</i> , А тобы жұлдыздары маңындағы сублимация процессінде силикатты тозақ бөлшектерінің орбиталық дамуы.....	73
<i>Минасянц Г.С., Минасянц Т.М., Томозов В.М.</i> Күннің минимум белсенді кезіндегі иондық энергиямен Fe/O қатынасының өзгеруі. I. күнде дақтар жоқ болғанда Fe және O иондарының энергетикалық спектрлері.....	81
<i>Минасянц Г.С., Минасянц Т.М., Томозов В.М.</i> Күн белсенділігі минимумында иондар қуатымен Fe/O мәнінің өзгеруі. II. Циклдің минимумында ғарыш сәулелерінің аномалды компоненттерінің ролі.....	86
<i>Тейфель В.Г., Каримов А.М., Харитонов Г.А.</i> , Сатурндағы аммиактың жұтылуы – 2009 жылы күн мен түннің теңелуі кезеңінде ендік вариациялар асимметриясы	91
<i>Каримов А.М., Лысенко П.Г., Тейфель В.Г.</i> , Сатурнның солтүстік жартышары - 2015 жылы метан және аммиактың жұтылуы	97
<i>Вдовиченко В.Д., Кириенко Г.А., Лысенко П.Г.</i> 2016 жылдың көріну маусымында юпитер дискісі бойынша метанның-аммиактың жұтылуын зерттеу I. Экватор аймағы	104
<i>Вдовиченко В.Д., Кириенко Г.А., Лысенко П.Г.</i> жылдың көріну маусымында юпитер дискісі бойынша метанның-аммиактың жұтылуын зерттеу. II. Ендік вариациялар	110
<i>Вдовиченко В.Д., Кириенко Г.А., Лысенко П.Г.</i> 2016 жылдың көріну маусымында Юпитерде метан-аммиак жұтылуын зерттеу III. Үлкен Қызыл Дақ (ҮҚД).....	118
<i>Демченко Б.И., Воропаев В.А., Комаров А.А., Молотов И.Е., Серебрянский А.В., Усольцева Л.А.</i> , Көптеген геотұрақты серіктердің кейбір сипаттамалары.....	124
<i>Демченко Б.И., Комаров А.А., Нифонтова М.В., Усольцева Л.А.</i> , Көру шегі аз CCD-матрицада ГТС бақылауларының астрономиялық өңдеулерінің әртүрлі әдістерінің салыстырмалы талдауы.....	129
<i>Демченко Б.И., Комаров А.А., Кругов М.А., Рева И.В., Серебрянский А.В., Усольцева Л.А.</i> , Тянь-Шань Астрономиялық Обсерваториясы бекетінде геотұрақты серіктерді бақылау жағдайы.....	135
<i>Шомищева С.А., Рева И.В., Кондратьева Л.Н., Отебай А.Б.</i> , Тянь-Шань Астрономиялық Обсерваториясының 1-метрлік телескобында фотометрлік жүйесін стандарттау.....	140
<i>Терещенко В.М.</i> , SSP-5A фотоэлектрлік фотометрі жұмысының сипаттамасы және ерекшеліктері.....	146
<i>Терещенко В.М., Шамро А.В.</i> , Абсолютті өлшемдер үшін спектрограф. Оптика-механикалық блоктың сызбасы және құрылымы.....	155

Теориялық зерттеулер

<i>Қалдыбекова Б.Қ., Решетова Г.В.</i> Арнайы ішектен жасалған тордың сандық нәтижелері.....	160
<i>Бакирова Э.А., Қадырбаева Ж.М.</i> Жүктелген дифференциалдық теңдеулер үшін сызықты көпнүктелі шеттік есептің шешілімділігі туралы.....	168
<i>Бесбаев Г.А., Көпжасарова А.А., Сапрыгина М.Б., Шалданбаев А.Ш.</i> Гурса операторының Крейн кеңістігіндегі жалқылығы туралы.....	176
<i>Жұмәлі А.С., Решетова Г.В.</i> Жерасты ерітінділеудің микроскопиялық динамикасын сандық моделдеу.....	188
<i>Бақтыбаев Қ., Дәлелханқызы А., Қиқымова І., Мырзагулов А.</i> Әсерлесуші бозондар моделін уран ядросының деформацияланған изотоптарына қолдану.....	195
<i>Көпжасарова А.А., Бесбаев Г.А., Абылкасымова Э. А., Шалданбаев А.Ш.</i> Толқын теңдеуінің шартарапты волтерлі есептерінің Крейннің кеңістігіндегі спектралдік таралымдары.....	203
<i>Шошманбаева М.Т., Көпжасарова А.А., Бесбаев Г.А., Шалданбаев А.Ш.</i> Толқындық теңдеуінің шартарапты шекаралық есебінің спектрлік қасиеттері.....	213
Қазақстанның астрономиялық ғылым 75 жыл.	224

СОДЕРЖАНИЕ

Исследование звезд и туманностей

<i>Серебрянский А.В., Гайнуллина Е.Р., Халикова А.В.</i> , Переменная звезда TYC3215-906-1: анализ кривой блеска классификация.....	5
<i>Кондратьева Л.Н., Рспаев Ф.К., Аймуратов Е.К., Отебай А.Б.</i> , Результаты спектральных и фотометрических наблюдений объекта V725 Тау.....	12
<i>Кондратьева Л.Н., Рспаев Ф.К., Аймуратов Е.К.</i> , Переменность планетарной туманности M1-65	22
<i>Павлова Л.А.</i> , Влияние магнитных полей на формирование околосветных структур	29
<i>Кокумбаева Р.И., Хруслов А.В., Кусакин А.В.</i> , Две новые переменные звезды GSC 3601-01531 и GSC 3601-01504... ..	35

Проблемы небесной механики и динамики звездных систем

<i>Дубовиченко С.Б., Джазаиров-Кахраманов А.В., Буркова Н.А., Ткаченко А.С.</i> , Радиационный $^2\text{H}^3\text{He}$ захват при астрофизических энергиях	41
<i>Зулыхаров А.Т., Коньсбаев Т.К., Чечин Л.М.</i> , Оценка времени релаксации галактик с учетом темной материи.....	50

Физика Солнца и тел солнечной системы

<i>Шестакова Л.И., Демченко Б.И.</i> , Действие светового давления на динамику атомов и ионов в осколочных дисках звезд класса А.....	55
<i>Демченко Б.И., Шестакова Л.И.</i> , Орбитальная эволюция пылевых частиц оливина в процессе сублимации около Солнца	64
<i>Шестакова Л.И., Демченко Б.И.</i> , Орбитальная эволюция силикатных пылевых частиц в процессе сублимации около звезд класса А	73
<i>Минасянц Г.С., Минасянц Т.М., Томозов В.М.</i> Изменение отношения Fe/O с энергией ионов в минимуме солнечной активности. I. Энергетические спектры ионов Fe и O при отсутствии пятен на Солнце.....	81
<i>Минасянц Г.С., Минасянц Т.М., Томозов В.М.</i> Изменение отношения Fe/O с энергией ионов в минимуме солнечной активности. II. Роль аномальной компоненты космических лучей в минимуме цикла.....	86
<i>Тейфель В.Г., Каримов А.М., Харитонова Г.А.</i> , Аммиачное поглощение на Сатурне - асимметрия широтных вариаций в период равноденствия 2009 года.....	91
<i>Каримов А.М., Лысенко П.Г., Тейфель В.Г.</i> , Северное полушарие Сатурна - поглощение метана и аммиака в 2015 году	97
<i>Вдовиченко В.Д., Кириенко Г.А., Лысенко П.Г.</i> Исследование молекулярного поглощения по диску Юпитера в сезон видимости 2016 года I. экваториальная область.....	104
<i>Вдовиченко В.Д., Кириенко Г.А., Лысенко П.Г.</i> , Исследование молекулярного поглощения на Юпитере в сезон видимости 2016 года II. Широтные вариации.....	110
<i>Вдовиченко В.Д., Кириенко Г.А., Лысенко П.Г.</i> Исследование молекулярного поглощения на Юпитере в сезон видимости 2016 года. III. Большое Красное Пятно (БКП)	118
<i>Демченко Б.И., Воропаев В.А., Комаров А.А., Молотов И.Е., Серебрянский А.В., Усольцева Л.А.</i> , Некоторые характеристики множества геостационарных спутников.....	124
<i>Демченко Б.И., Комаров А.А., Нифонтова М.В., Усольцева Л.А.</i> , Сравнительный анализ различных методов астрометрической обработки наблюдений ГСС на CCD-матрице с малым полем зрения.....	129
<i>Демченко Б.И., Комаров А.А., Кругов М.А., Рева И.В., Серебрянский А.В., Усольцева Л.А.</i> , Условия наблюдений геостационарных спутников на пункте Тянь-Шанская Астрономическая Обсерватория	135
<i>Шомищева С.А., Рева И.В., Кондратьева Л.Н., Отебай А.Б.</i> , Стандартизация фотометрической системы 1-метрового телескопа Тянь-Шанской Астрономической Обсерватории.....	140
<i>Терещенко В.М.</i> , Характеристики и особенности работы фотоэлектрического фотометра SSP-5A	146
<i>Терещенко В.М., Шамро А.В.</i> , Спектрограф для абсолютных измерений. Схема и конструкция оптико-механического блока.....	152

Теоретические исследования

<i>Калдыбекова Б. К., Решетова Г. В.</i> Численные результаты специальной сетки из струн.....	160
<i>Бакирова Э.А., Кадирбаева Ж.М.</i> О разрешимости линейной многоточечной краевой задачи для нагруженных дифференциальных уравнений.....	168
<i>Бесбаев Г.А., Көпжасарова А.А., Сапрыгина М.Б., Шалданбаев А.Ш.</i> О самосоряженности оператора Гурса в пространстве Крейна.....	176
<i>Жумали А.С., Решетова Г.В.</i> Численное моделирование микроскопической динамики подземного выщелачивания.....	188
<i>Бактыбаев К., Далелханкызы А., Кикымова I., Мырзабаев А.</i> Применение модели взаимодействующих бозонов в деформированных изотопах ядра урана.....	195
<i>Көпжасарова А.А., Бесбаев Г.А., Абылкасымова Э. А., Шалданбаев А.Ш.</i> Спектральные разложения решения вольтерровых нелокальных краевых задач волнового уравнения.....	203
<i>Шомаманбаева М.Т., Көпжасарова А.А., Бесбаев Г.А., Шалданбаев А.Ш.</i> Спектральные свойства нелокальной краевой задачи волнового уравнения	213
75 лет казахстанской астрономической науке.....	224

CONTENTS

Investigation of stars and nebulae

<i>Serebryanskiy A.V., Gaynullina E.R., Khalikova A.V.</i> Variable star TYC3215-906-1: light curve analyses and classification	5
<i>Kondratyeva L., Rspaev F., Aimuratov Ye., Otebay A.</i> Results of the spectral and photometric observations of the object V725 Tau	12
<i>Kondratyeva L., Rspaev F., Aimuratov Ye.</i> , Variability of the planetary nebula M1-65.....	22
<i>Pavlova L.A.</i> , The influents magnetic field on the forming circumstellar structure.....	29
<i>Kokumbaeva R.I., Khruslov A.V., Kusakin A.V.</i> , GSC 3601-01531 and GSC 3601-01504, two new variable stars.....	35

Problems of celestial mechanics and dynamics of stellar systems

<i>Dubovichenko S.B., Dzhazairov-Kakhramanov A.V., Burkova N.A., Tkachenko A.S.</i> , Radiative $^2\text{H}^3\text{He}$ capture at astrophysical energies	41
<i>Zulpykharov A. T., Konysbayev T.K., Chechin L.M.</i> The relaxation time estimation for galaxies with account of Dark matter.....	50

Physics of sun and bodies of the Solar system

<i>Shestakova L.I., Demchenko B.I.</i> , The action of radiation pressure on the dynamics of atoms and ions in debris disks of A-type stars.....	55
<i>Demchenko B.I., Shestakova L.I.</i> , Orbital evolution of olivine dust grain during sublimation process near the Sun.....	64
<i>Shestakova L.I., Demchenko B.I.</i> , Orbital evolution of silicate dust particles during sublimation near A-type stars.....	73
<i>Minasyants G.S., Minasyants T.M., Tomozov V.M.</i> Variations of Fe/O Ratio with Ion's Energies in the Solar Activity Minimum. I. Energy Spectra of Fe and O Ions on the Spotless Sun	81
<i>Minasyants G.S., Minasyants T.M., Tomozov V.M.</i> Variations of Fe/O Ratio with Ion's Energies in the Solar Activity Minimum. II. Role of anomalous component of the cosmic rays in a cycle minimum.....	86
<i>Tejfe V.G.I., Karimov A.M., Kharitonova G.A.</i> The ammonia absorption in Saturn – an asymmetry of latitudinal variations at the 2009 equinox.....	91
<i>Karimov A.M., Lysenko P.G., Tejfe V.G.I., Kharitonova G.A.</i> , Northern hemisphere of SATURN – the methane and ammonia absorption in 2015.....	97
<i>Vdovichenko V.D., Kirienko G.A., Lysenko P.G.</i> , The study of molecular absorption over Jovian disk in season of 2016 visibility. I. Equatorial area.....	104
<i>Vdovichenko V.D., Kirienko G.A., Lysenko P.G.</i> The study of molecular absorption on Jupiter in visibility season of 2016. II. Latitudinal variations.....	110
<i>Vdovichenko V.D., Kirienko G.A., Lysenko P.G.</i> The study of molecular absorption on Jupiter in visibility season of 2016. III. Great Red Spot (GRS).....	118
<i>Demchenko B. I., Komarov A. A., Molotov I. E., Serebryansky A. V., Usoltseva L. I., Voropaev V.A.</i> Some features of geostationary satellites ensemble.....	124
<i>Demchenko B. I., Komarov A. A., Nifontova M.V., Usoltseva L. I.</i> , Comparative analysis of several methods of astrometric processing of the GSS observations using CCD-cameras with narrow field of view.....	129
<i>Demchenko B. I., Komarov A. A., Krugov M.A., Reva I.V., Serebryansky A. V., Usoltseva L. I.</i> , Condition of observations of geostationary satellites at Tien Shan astronomical observatory.....	135
<i>Shomshekova S. A., Reva I.V., Kondratyeva L.N., Otebay A.B.</i> , Standardization of the photometric system of the 1-meter telescope of Tien-Shan Astronomical Observatory.....	140
<i>Tereschenko V. M.</i> , The characteristics and peculiarities of the photoelectrical photometer SSP-5A operation.....	146
<i>Tereschenko V. M., Shamro A. V.</i> , Spectrograph for absolute measurements. Scheme and construction of the optic-mechanic block.....	152

Theoretical studies

<i>Kaldybekova B.K., Reshetova G. V.</i> Numerical results of special grid of strings.....	160
<i>Bakirova E.A., Kadirbayeva Zh.M.</i> On a solvability of linear multipoint boundary value problem for the loaded differential equations.....	168
<i>Besbayev G. A., Kopzhasarova A.A., Saprygina M.B., Shaldanbayev A.Sh.</i> On self-conjugation of the operator of goursat in crane space	176
<i>Zhumali A.S., Reshetova G.V.</i> Numerical modelling of microscopic dynamics of in-situ leaching.....	188
<i>Baktybaev K., Dalelkhankyzy A., Kyqymova I., Myrzabaev A.</i> Applying the model of interacting bosons in a deformed nucleus of uranium isotopes.....	195
<i>Kopzhasarova A.A., Besbayev G. A., Abylkassymova E.A., Shaldanbayev A.SH.</i> Spectral resolutions of solution of voltaire nonlocal boundary value problems of a wave equation.....	203
<i>Shomanbayeva M. T., Kopzhasarova A.A., Besbayev G. A., Shaldanbayev A.Sh.</i> Spectral properties of a nonlocal boundary value problem of a wave equation.....	213
75 years of Kazakhstan's astronomical science	224

**Publication Ethics and Publication Malpractice
in the journals of the National Academy of Sciences of the Republic of Kazakhstan**

For information on Ethics in publishing and Ethical guidelines for journal publication see <http://www.elsevier.com/publishingethics> and <http://www.elsevier.com/journal-authors/ethics>.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see <http://www.elsevier.com/postingpolicy>), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service <http://www.elsevier.com/editors/plagdetect>.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:

www.nauka-nanrk.kz

<http://www.physics-mathematics.kz>

<http://road.issn.org/issn/2518-1726>

Редактор *М. С. Ахметова, Д.С. Аленов, Т.А. Апендиев*
Верстка на компьютере *А.М. Кульгинбаевой*

Подписано в печать 25.09.2016.
Формат 60x881/8. Бумага офсетная. Печать – ризограф.
14 п.л. Тираж 300. Заказ 5.