

ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

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 (315)

**ҚЫРКУЙЕК – ҚАЗАН 2017 Ж.
СЕНТЯБРЬ – ОКТЯБРЬ 2017 Г.
SEPTEMBER – OCTOBER 2017**

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

Б а с р е д а к т о р ы
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)
Бошқаев К.А. PhD докторы (Қазақстан)
Сұраған Д. корр.-мүшесі (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)

«ҚР ҰҒА Хабарлары. Физика-математикалық сериясы».

ISSN 2518-1726 (Online), ISSN 1991-346X (Print)

Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.)
Қазақстан республикасының Мәдениет пен ақпарат министрлігінің Ақпарат және мұрағат комитетінде
01.06.2006 ж. берілген №5543-Ж мерзімдік басылым тіркеуіне қойылу туралы куәлік

Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., 220, тел.: 272-13-19, 272-13-18,
www.nauka-nanrk.kz / physics-mathematics.kz

© Қазақстан Республикасының Ұлттық ғылым академиясы, 2017

Типографияның мекенжайы: «Аруна» ЖК, Алматы қ., Муратбаева көш., 75.

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

Редакционная коллегия:

Джумадилаев 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. чл.-корр. (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 2518-1726 (Online), ISSN 1991-346X (Print)

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

© Национальная академия наук Республики Казахстан, 2017

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

E d i t o r i n c h i e f
doctor of physics and mathematics, professor, academician of NAS RK **G.M. Mutanov**

E d i t o r i a l b o a r d:

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. corr. member. (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 2518-1726 (Online), ISSN 1991-346X (Print)

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, 2017

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 315 (2017), 5 – 12

A.A. Kulzhumiyeva¹, Zh.A. Sartabanov²¹M. Utemisov West-Kazakhstan State University, Uralsk, Kazakhstan;²K. Zhubanov Aktobe Regional State University, Aktobe, KazakhstanE-mail: aiman-80@mail.ru, sartabanov42@mail.ru

REDUCTION OF LINEAR HOMOGENEOUS D_e -SYSTEMS TO THE JORDAN CANONICAL FORM

Abstract. In this note we prove a theorem about reducibility to the canonical form of a linear homogeneous system with differentiation operator on diagonal and multiperiodic matrix constant on the diagonal. On the basis of the results obtained, it is possible to find out the structure of the solutions and investigate the conditions of the existence and uniqueness of the (θ, ω, ω) - periodic solution of the linear D_e -system of equations. When investigating periodic solutions of linear systems of first order partial differential equations, it becomes necessary to reduce matrices with variable elements to convenient form. In this connection, we note the results of [1-2] and commentaries on them in monographs [3-5]. It is known that the study of the problems of multiperiodic solutions of systems of first order partial D_e -equations with the same principal part originates in works [6-7]. On their basis, further qualitative studies have been continued in [8-11].

Key words: linear homogeneous system, differentiation operator, Jordan canonical form, multiperiodic matrix, main diagonal, vector-period.

The article is devoted investigation of reduction of a linear D_e -system of the form

$$D_e x = A(\sigma)x \quad (1)$$

with the differential operator $D_e = \frac{\partial}{\partial \tau} + \left\langle e, \frac{\partial}{\partial t} \right\rangle$ to the canonical form

$$D_e x = J(\sigma)x, \quad (1^*)$$

where $\tau \in (-\infty, +\infty) = R$, $t = (t_1, \dots, t_m) \in R \times \dots \times R = R^m$, $\frac{\partial}{\partial t} = \left(\frac{\partial}{\partial t_1}, \dots, \frac{\partial}{\partial t_m} \right)$ is a vector

operator, $e = (1, \dots, 1)$ – m -vector, $\langle \cdot, \cdot \rangle$ denotes the scalar product, $\sigma = t - e\tau$, $A(\sigma)$ an $n \times n$ -matrix, which satisfies condition

$$A(\sigma + k\omega) = A(\sigma) \in C_\sigma^{(e)}(R^m), \quad \forall k \in Z^m \quad (2)$$

with multiple vector-periods $k\omega = (k_1\omega_1, \dots, k_m\omega_m)$, $\omega = (\omega_1, \dots, \omega_m)$, $k = (k_1, \dots, k_m)$

from the set of integer vectors Z^m . $J(\sigma)$ an $n \times n$ -matrix of the Jordan form possessing the properties of multiperiodicity with the same ω period and smoothness e in $\sigma \in R^m$:

$$J(\sigma + k\omega) = J(\sigma) \in C_\sigma^{(e)}(R^m), \quad \forall k \in Z^m. \quad (2^*)$$

Variable matrices $A(\sigma)$ and $J(\sigma)$ are called constants on the diagonal $t = e\tau$.

Let $\lambda_j(\sigma)$ be eigenvalues of the matrix $A(\sigma)$ of multiplicity k_j , $j = \overline{1, s}$, possessing the following properties.

1⁰. Continuous differentiability: $\lambda_j(\sigma) \in C_\sigma^{(e)}(R^m)$, $j = \overline{1, n}$.

2⁰. Periodicity with period $\omega = (\omega_1, \dots, \omega_m)$: $\lambda_j(\sigma + k\omega) = \lambda_j(\sigma)$, $j = \overline{1, n}$, $\sigma \in R^m$, $k \in Z^m$.

3⁰. Property of having fixed sign $\lambda_j(\sigma)$ for each $j = \overline{1, n}$:

a) $\lambda_j(\sigma) < 0$, $\forall \sigma \in R^m$ or

b) $\lambda_j(\sigma) = 0$, $\forall \sigma \in R^m$ or

c) $\lambda_j(\sigma) > 0$, $\forall \sigma \in R^m$.

4⁰. Separation of eigenvalues:

a) for $j \neq l$ $\lambda_j(\sigma) \neq \lambda_l(\sigma)$, $\forall \sigma \in R^m$ or

b) for $j \neq l$ $\lambda_j(\sigma) = \lambda_l(\sigma)$, $\forall \sigma \in R^m$,

i.e. for each value j the eigenvalue $\lambda_j(\sigma)$ has constant multiplicity $k_j = const$ for all $\sigma \in R^m$.

5⁰. Each of the sets $Re\{\lambda_j(\sigma)\}$ and $Im\{\lambda_j(\sigma)\}$ has properties 1⁰-4⁰.

The properties 1⁰-5⁰ are briefly called Λ -properties of the matrix $A(\sigma)$.

It is obvious that characteristic matrix $\lambda E - A(\sigma) = H(\lambda, \sigma)$ has for all $\sigma \in R^m$ constant rank n and its invariant λ -polynomials $i_1(\lambda, \sigma), \dots, i_n(\lambda, \sigma)$ such that, starting with the second, they are a divisor of the previous one, $i_1(\lambda, \sigma), \dots, i_r(\lambda, \sigma)$ are polynomials of degree greater than zero with respect to λ and

$$i_{r+1}(\lambda, \sigma) = \dots = i_n(\lambda, \sigma) = 1.$$

Then the characteristic matrix $H(\lambda, \sigma)$ is represented by relations

$$H(\lambda, \sigma) = P(\lambda, \sigma) \text{diag}[i_1(\lambda, \sigma), \dots, i_r(\lambda, \sigma), 1, \dots, 1] Q(\lambda, \sigma), \quad (3)$$

where $P(\lambda, \sigma)$ and $Q(\lambda, \sigma)$ are non-singular $n \times n$ -matrices that λ -polynomials are with independent of λ determinants $\det P(\lambda, \sigma) = p(\sigma) \neq 0$ and $\det Q(\lambda, \sigma) = q(\sigma) \neq 0$.

Companion matrices of invariant polynomials

$$i_j(\lambda, \sigma) = \lambda^{n_j} - \alpha_{j1}(\sigma)\lambda^{n_j-1} - \dots - \alpha_{jn_j}(\sigma), \quad j = \overline{1, r}, \quad n_1 + \dots + n_r = n$$

denote by

$$A_j^*(\sigma) = \begin{pmatrix} 0 & 1 & 0 & \dots & 0 \\ 0 & 0 & 1 & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \dots & 1 \\ \alpha_{jn_j}(\sigma) & \alpha_{jn_j-1}(\sigma) & \alpha_{jn_j-2}(\sigma) & \dots & \alpha_{j1}(\sigma) \end{pmatrix}, \quad j = \overline{1, r}. \quad (4)$$

It is obvious that the representation (3) can be obtained on the basis of elementary transformations known from theory of λ -matrices [12] under which properties of multiperiodicity and continuous

differentiability in σ for matrices participating in relation (3) are preserved. Consequently, these properties also hold for the matrices (4).

In [13], the condition of equivalence of matrix $\lambda E - A(\sigma)$ to the matrix with one invariant λ -polynomials are established and theorem of reducibility of the matrix $A(\sigma)$ to the Jordan normal form by multiperiodic continuously differentiable non-singular transformation matrix is proved.

Moreover, system (1) was equivalent to one equation with higher order D_e operator with companion matrix of the form (4).

In this article we raise the question about investigating the reducibility of system (1) to the D_e -system with the matrix of Jordan normal form, when the matrix (2) with several invariant polynomials satisfies the conditions 1⁰-5⁰.

In other words, in [13] we consider D_e -system, which is equivalent to one D_e -equation of order n , and in this case, by (3), our system (1) breaks up into r linear D_e -equations of orders n_1, \dots, n_r ($n_1 + n_2 + \dots + n_r = n$). The essence of the problem is to reduce this general D_e -system (1) to D_e -system with matrix $J(\sigma)$ of the Jordan canonical normal form, where Λ -properties of matrix $A(\sigma)$ are essential value.

When raising the question, it is obvious that this study is adjacent to the studies [14-19].

To solve the problem posed, we use the true normal form $A^*(\sigma)$ of matrix $A(\sigma)$, which are related by a similarity relation

$$A^*(\sigma) = L^{-1}(\sigma)A(\sigma)L(\sigma). \quad (5)$$

The relation (5) to be a result of the representation (3), where

$$A^*(\sigma) = \text{diag}[A_1^*(\sigma), \dots, A_r^*(\sigma)]$$

with diagonal elements of the form (4), $L(\sigma)$ is a non-singular continuously differentiable ω -periodic matrix:

$$L(\sigma + k\omega) = L(\sigma) \in C_\sigma^{(e)}(R^m), \quad \forall k \in Z^m. \quad (6)$$

Relations (5)-(6), as well as (3)-(4) are obtained on the basis of methods of the theory of equivalent transformations of polynomial matrices for which smoothness and multiperiodicity of the matrices are saved.

Further, in view of (5), (6) and the change

$$x = L(\sigma)z, \quad \det L(\sigma) \neq 0, \quad L(\sigma + k\omega) = L(\sigma), \quad k \in Z^m \quad (7)$$

system (1) is reducible to the system

$$D_e z = A^*(\sigma)z, \quad (8)$$

which is equivalent to the system of subsystems

$$D_e z_j = A_j^*(\sigma)z_j, \quad (8_j)$$

where $A_j^*(\sigma)$ has the form (4), $j = \overline{1, r}$, $z = (z_1, \dots, z_r)$.

In the case of the known elementary divisors of matrix $A(\sigma)$ the system (1), and, consequently, the system (8) can be reduced to an even simpler form.

Indeed, in view of (2) and Λ -properties of the matrix $A(\sigma)$, we have full information about its eigenvalues. Hence, it exists a non-singular, really smooth ω -periodic matrix of the transformation $\tilde{L}(\sigma)$ such that

$$\tilde{A}(\sigma) = \tilde{L}^{-1}(\sigma)A(\sigma)\tilde{L}(\sigma), \quad (\tilde{5})$$

where $\tilde{A}(\sigma) = \text{diag}[\tilde{A}_1(\sigma), \dots, \tilde{A}_l(\sigma)]$ is the second true form of matrix $A(\sigma)$, $\tilde{A}(\sigma)$ have the form (4), in which the coefficients of the degree are non-zero elements of the last row

$$(\lambda - \lambda_j(\sigma))^{n_j} = \lambda^n + \beta_{j1}(\sigma)\lambda^{n-1} + \beta_{j2}(\sigma)\lambda^{n-2} + \dots + \beta_{jn_j}(\sigma),$$

which are an elementary divisor of the characteristic matrix (3). We write the properties of matrix $\tilde{L}(\sigma)$ in the form

$$\tilde{L}(\sigma + k\omega) = \tilde{L}(\sigma) \in C_\sigma^{(e)}(R^m), k \in Z^m, \tilde{L}(\sigma) \neq 0. \quad (\tilde{6})$$

Here, the eigenvalues $\lambda_j(\sigma)$, $j = \overline{1, n}$ are assumed to be real-valued.

Then, by the relations $(\tilde{5})$, $(\tilde{6})$ and the change

$$x = \tilde{L}(\sigma)\tilde{z} \quad (\tilde{7})$$

system (1) can be represented in the form

$$D_e \tilde{z} = \tilde{A}(\sigma)\tilde{z}, \quad (\tilde{8})$$

which consists from l subsystems

$$D_e \tilde{z}_\rho = \tilde{A}_\rho(\sigma)\tilde{z}_\rho, \quad (\tilde{8}_\rho)$$

where $\rho = \overline{1, l}$, $\tilde{z}_\rho = (\tilde{z}_{\rho 1}, \dots, \tilde{z}_{\rho n_\rho})$, $n_1 + \dots + n_l = n$, $\tilde{z} = (\tilde{z}_1, \dots, \tilde{z}_l)$.

Next, we should consider the reduction of system (1) to system with Jordan canonical form.

In the case of simple roots of matrices $A_j^*(\sigma)$:

$$\lambda_{ji}(\sigma) \neq \lambda_{jk}(\sigma), \quad \sigma \in R^m, \quad (i \neq k)$$

of the characteristic equation

$$\det[\lambda E - A_j(\sigma)] = 0, \quad i, k \in \overline{1, n_j}, \quad j = \overline{1, r}, \quad n_1 + \dots + n_r = n$$

it is not difficult to verify that the Vandermonde matrix of the form

$$B_j(\sigma) = \begin{pmatrix} 1 & 1 & \dots & 1 \\ \lambda_{j1}(\sigma) & \lambda_{j2}(\sigma) & \dots & \lambda_{jn_j}(\sigma) \\ \lambda_{j1}^2(\sigma) & \lambda_{j2}^2(\sigma) & \dots & \lambda_{jn_j}^2(\sigma) \\ \dots & \dots & \dots & \dots \\ \lambda_{j1}^{n_j-1}(\sigma) & \lambda_{j2}^{n_j-1}(\sigma) & \dots & \lambda_{jn_j}^{n_j-1}(\sigma) \end{pmatrix}$$

satisfies the matrix equation

$$A_j(\sigma)B_j(\sigma) = B_j(\sigma)J_j(\sigma),$$

where $J_j(\sigma) = \text{diag}[\lambda_{j1}(\sigma), \dots, \lambda_{jn_j}(\sigma)]$ and also

$$\det B_j(\sigma) = \prod_{n_j \geq i > k \geq 1} (\lambda_{ji}(\sigma) - \lambda_{jk}(\sigma)) \neq 0.$$

Consequently, in this case the system (8_i) under conditions (2) and 1^0-5^0 is reducible to the Jordan canonical form

$$D_e y_j = J_j(\sigma)y_j \quad (9_j)$$

by non-singular linear transformation

$$z_j = B_j(\sigma)y_j, \quad \det B_j(\sigma) \neq 0, \quad B_j(\sigma + k\omega) = B_j(\sigma) \in C_\sigma^{(e)}(R^m), \quad k \in Z^m, \quad (8_j^*)$$

where $j = \overline{1, r}$, $\sigma \in R^m$.

Then for $\sigma \in R^m$ the transformation

$$z = B(\sigma)y, \det B(\sigma) \neq 0, B(\sigma + k\omega) = B(\sigma) \in C_{\sigma}^{(e)}(R^m), k \in Z^m, (\mathfrak{B}^*)$$

leads system (8) to the D_e -system of Jordan canonical form

$$D_e y = J(\sigma)y, (9)$$

where $B(\sigma) = \text{diag}[B_1(\sigma), \dots, B_r(\sigma)]$, $J(\sigma) = \text{diag}[J_1(\sigma), \dots, J_r(\sigma)]$, $y = (y_1, \dots, y_r)$.

In the case of multiple elementary divisors of matrix $A(\sigma)$ will be necessary to use its second normal form $\tilde{A}(\sigma)$ from system $(\tilde{\mathfrak{B}})$ and its subsystems $(\tilde{\mathfrak{B}}_{\rho})$ with matrices $\tilde{A}_{\rho}(\sigma)$.

To reduce the matrix $\tilde{A}_{\rho}(\sigma)$ to the Jordan normal form $J_{\rho} = \lambda_{\rho}E_{\rho} + I_{\rho}$ with identity matrix E_{ρ} and first off-diagonal oblique range I_{ρ} it is necessary to construct matrix $T_{\rho}(\sigma)$ with elements

$$t_{ij}^{(\rho)}(\sigma) = \begin{cases} \sum_{k=1}^j C_{i-1}^{j-1} \lambda_{\rho}^{i-k}(\sigma), & j \leq i, \\ \sum_{k=1}^i C_{i-1}^{j-1} \lambda_{\rho}^{i-k}(\sigma) = b_{ii}, & j > i, \end{cases}$$

where C_i^j is total number of combinations of i in a total of j .

The reader will have no difficulty in verifying that [20]

$$A_{\rho}(\sigma)T_{\rho}(\sigma) = T_{\rho}(\sigma)J_{\rho}(\sigma)$$

and also $\det T_{\rho}(\sigma) = 1$.

Then the change

$$\tilde{z}_{\rho} = T_{\rho}(\sigma)\tilde{y}_{\rho}$$

leads the system $(\tilde{\mathfrak{B}}_{\rho})$ to the system

$$D_e \tilde{y}_{\rho} = J_{\rho}(\sigma)\tilde{y}_{\rho}$$

with a Jordan cage $J_{\rho} = \lambda_{\rho}E_{\rho} + I_{\rho}$.

Consequently, the change

$$\tilde{z} = T(\sigma)y \quad (\tilde{\mathfrak{B}}^*)$$

system (8) leads to the system (9) of the Jordan normal form, where $T(\sigma) = \text{diag}[T_1(\sigma), \dots, T_l(\sigma)]$ is non-singular ω -periodic, smooth transformation matrix.

In the case of complex eigenvalues, as can be seen from structures of matrices $T_{\rho}(\sigma)$ and $J_{\rho}(\sigma)$, matrices $T(\sigma)$ and $J(\sigma)$ are complex-valued. In view the condition 5⁰ its real and imaginary parts are distinguished without any special difficulties for all $\sigma \in R^m$.

Thus, by transformations (6)-(6^{*}), (7)-(7^{*}) and (8^{*})-(8^{*}) non-singular linear change

$$x = L^*(\sigma)y \quad (1^*)$$

leads the D_e -system (1) to the D_e -system (9) with Jordan matrix $J(\sigma)$. The matrix $L^*(\sigma)$ is transformation matrix $L^*(\sigma) = L(\sigma)B(\sigma)$ and it has properties

$$\det L^*(\sigma) \neq 0, L^*(\sigma + k\omega) = L^*(\sigma), k \in Z^m. (1^{**})$$

We call system (9) the Jordan canonical D_e -system of system (1).

We formulate the main result in the form of the following theorem.

Theorem. Let the matrix $A(\sigma)$ possessing the property (2) has eigenvalues $\lambda_j(\sigma)$, $j = \overline{1, n}$, satisfying the conditions 1⁰-5⁰. Then the system (1) can be reduced to the Jordan canonical D_e -system (9) by linear transformation (1^*) - (1^{**}) .

As an application of the theorem proved, we consider D_e -system of triangular type

$$\begin{cases} D_e x = A_{11}(\sigma)x, \\ D_e y = A_{21}(\sigma)x + A_{22}(\sigma)y, \end{cases} \quad (10)$$

where x is n_1 -vector-function, y is n_2 -vector-function, $A_{11}(\sigma)$, $A_{21}(\sigma)$ and $A_{22}(\sigma)$ are multiperiodic with ω -vector-period, smooth in $\sigma \in R^m$ matrices of order $n_1 \times n_1$, $n_2 \times n_2$, $n_{21} = n_2 \times n_1$.

We suppose that the block matrix

$$A(\sigma) = \begin{pmatrix} A_{11}(\sigma) & O \\ A_{21}(\sigma) & A_{22}(\sigma) \end{pmatrix} \quad (11)$$

satisfies the condition

$$A(\sigma + k\omega) = A(\sigma) \in C_\sigma^{(e)}(R^m), k \in Z^m (11^*)$$

where O is zero block. The diagonal blocks $A_{11}(\sigma)$ and $A_{22}(\sigma)$ have Λ -properties, therefore, these blocks have Jordan forms

$$J_j(\sigma) = L_j^{-1}(\sigma)A_{jj}(\sigma)L_j(\sigma), j = 1, 2 (12^*)$$

with non-singular ω -periodic and smooth matrices

$$L_j(\sigma + k\omega) = L_j(\sigma) \in C_\sigma^{(e)}(R^m), \det L_j(\sigma) \neq 0, k \in Z^m, j = 1, 2. (12^{**})$$

Then by theorem linear non-singular ω -periodic, smooth in $\sigma \in R^m$ transformation of form

$$\begin{cases} x = L_1(\sigma)u, \\ y = L_2(\sigma)v \end{cases} \quad (12)$$

leads system (10) to a linear system

$$\begin{cases} D_e u = J_1(\sigma)u, \\ D_e v = B(\sigma)u + J_2(\sigma)v \end{cases} \quad (13)$$

with diagonal blocks $J_1(\sigma)$ and $J_2(\sigma)$ of the Jordan canonical form, where

$$B(\sigma) = L_2^{-1}(\sigma)A_{21}(\sigma)L_1(\sigma)$$

is smooth, ω -periodic in $\sigma \in R^m$ $n_2 \times n_1$ -matrix.

It is obvious that the system (13) has more convenient form in comparison with the system (10) for integration and qualitative investigation.

The system of form (13) can be called the semi-canonical form of the triangular system (10).

Thus, we can give the following corollary to theorem proved.

Corollary. Let triangular matrix (11) satisfying the condition (11^*) has Λ -properties. Then the system (10) by transformation (12)- (12^*) - (12^{**}) is reduced to the semi-canonical D_e -system (13).

In conclusion, we note that the problem posed of studies we have used the methods of [20].

REFERENCES

- [1] Sibuya Y. (1965) Some Global Properties of Matrices of Functions of One Variable // Math. Annal. № 161. P.67-77.
- [2] Sibuya Y. (1962) Formal Solutions of a Linear Ordinary Differential Equation of the n -th Order at a Turning Point // Funkcial. Ekvac. № 4. P.115-139.
- [3] Vazov V. (1968) Asymptotic decomposition of solutions of ordinary differential equations. M.: Mir. (in Russ.)
- [4] Samoilenko A.M. (1987) The elements of mathematical theory of multifrequency oscillations. Invariant tors. M.: Nauka. (in Russ.)
- [5] Lappo-Danilevskiy I.A. (1957) Using functions from matrix to the theory of linear systems of ordinary differential equations. M.: GITTL. (in Russ.)
- [6] Kharasahal V.H. (1970) Almost periodic solutions of ordinary differential equations. Alma-Ata: Nauka. (in Russ.)
- [7] Umbetzhano D.U. (1979) Almost multiperiodic solutions of partial differential equations. Alma-Ata: Nauka. (in Russ.)
- [8] Sartabanov Zh.A. (1989) About single method of studying periodic solutions of equations in partial derivatives of special form // News. Physico-mathematical series. № 1. P.42-48. (in Russ.)
- [9] Sartabanov Zh.A. (2004) The condition of periodicity solutions of differential systems with multivariate time // News. Physico-mathematical series. № 5. P.44-48. (in Russ.)
- [10] Kulzhumiyeva A.A., Sartabanov Zh.A. (2007) Periodic in multivariate time of solutions of system equations with differential operator according to the direction of vector field // Eurasian Mathem. Journal. № 1. - P. 62-72. (in Russ.)
- [11] Kulzhumiyeva A.A. (2008) Research of periodic solutions lead to canonic form of systems with linear differential operator in multivariate time // Eurasian Mathem. Journal. № 2. - P. 69-73. (in Russ.)
- [12] Gantmaher F.R. (1966) Matrix theory. M.: Nauka. (in Russ.)
- [13] Kulzhumiyeva A.A., Sartabanov Zh.A. (2016) On reducibility of linear D_e -system with constant coefficients on the diagonal to D_e -system with Jordan matrix in the case of equivalence of its higher order one equation // Bulletin of the Karaganda university. Mathematics series. №4(84). P. 88-93. (in Russ.)
- [14] Kulzhumiyeva A.A., Sartabanov Zh.A. (2007) Periodic with variable period solutions of system of differential equations of multivariate time // Mathematical journal. t.7. № 2(24). - P.52-57. (in Russ.)
- [15] Kulzhumiyeva A.A., Sartabanov Zh.A. (2007) To the question of periodic solutions in multivariate time of system D_α -equations // Bulletin of the Orenburg university. № 3. - P.155-157. (in Russ.)
- [16] Kulzhumiyeva A.A., Sartabanov Zh.A. (2007) Periodic with multivariate time solutions of system of the quasi-linear differential equations in partial derivative // International Conference «Analysis and Singularities», dedicated to 70th anniversary of V.I. Arnold. Moscow. P.156-158.
- [17] Kulzhumiyeva A.A., Sartabanov Zh.A. (2009) Oscillations in quasi-linear system with operator of the differentiation on diagonals of multivariate time // International Conference «Modern problems of mathematics, mechanics and their applications» dedicated to the 70-th anniversary of rector of MSU academic V.A. Sadovnichy. Moscow. P.203.
- [18] Muhambetova B.Zh., Sartabanov Zh.A., Kulzhumiyeva A.A. (2015) Multiperiodic solutions of systems of equations with one quasi-linear differential operator in partial derivatives of the first order // Bulletin of the Karaganda university. Mathematics series. № 2(78). P. 112-117. (in Russ.)
- [19] Kulzhumiyeva A.A., Sartabanov Zh.A. (2017) On multiperiodic integrals of a linear system with the differentiation operator in the direction of the main diagonal in the space of independent variables // Eurasian Mathematical Journal. № 1. v. 8. P. 67-75.
- [20] Kulzhumiyeva A.A., Sartabanov Zh.A. (2013). Periodic solutions of system of differential equations with multivariate time. Uralsk: RIC WKSU. (in Russ.)

А.А. Кульжумиева¹, Ж.А. Сартабанов²

¹М. Өтемісов атындағы Батыс-Қазақстан мемлекеттік университеті, Орал, Қазақстан

²Қ.Жұбанов атындағы Ақтөбе өңірлік мемлекеттік университеті, Ақтөбе, Қазақстан

СЫЗЫҚТЫ БІРТЕКТІ D_e -ЖҮЙЕЛЕРДІ ЖОРДАНДЫҚ КАНОНДЫҚ ТҮРГЕ КЕЛТІРУ

Аннотация. Мақалада көп периодты тұрақты матрицамен және диагональ бойынша дифференциалдау операторымен сызықты біртекті жүйенің канондық түрге келтірілуі жөнінде теорема дәлелденген. Алынған нәтижелер негізінде D_e -сызықты теңдеулер жүйесінің (θ, ω, ω) -периодты шешімінің бар және жалғыз болуының шартын зертеп және шешімнің құрылымын анықтауға болады. Бірінші ретті дербес туындылы теңдеулердің сызықты жүйелерінің периодты шешімдерін зерттеу кезінде айнымалы элементті матрица-

ларды ыңғайлы түрге келтірілу қажеттілігі туындайды. Осы байланыста [1-2] жұмыстарының нәтижелерін және [3-5] монографияларында оларға түсіндірмелерді ескереміз. Негізгі бөлімі бірдей бірінші ретті дербес туындылы D_e -теңдеулер жүйесінің көп периодты шешімдерінің сұрақтарын зерттеу [6-7] еңбектерінен бастау алатыны белгілі. Олардың негізінде кейбір әрі қарай сапалы зерттеулері [8-11] жұмыстарында жалғастырған.

Кілт сөздер: сызықты біртекті жүйе, дифференциалдық оператор, жордандық канондық түрі, көп периодты матрица, негізгі диагональ, вектор-период.

УДК 35В10

А.А. Кульжумиева¹, Ж.А. Сартабанов²

¹Западно-Казахстанский государственный университет им. М. Утемисова, Уральск, Казахстан;

²Актюбинский региональный государственный университет им. К. Жубанова, Актюбе, Казахстан

ПРИВЕДЕНИЕ ЛИНЕЙНЫХ ОДНОРОДНЫХ D_e -СИСТЕМ К ЖОРДАНОВОМУ КАНОНИЧЕСКОМУ ВИДУ

Аннотация. В заметке доказана теорема о приводимости к каноническому виду линейной однородной системы с оператором дифференцирования по диагонали и многопериодической матрицей постоянной на диагонали. На основе полученных результатов можно выяснить структуры решений и исследовать условия существования и единственности (θ, ω, ω) -периодического решения линейной D_e -системы уравнений. При исследовании периодических решений линейных систем уравнений в частных производных первого порядка возникает необходимость приведения матриц с переменными элементами к удобному виду. В этой связи отметим результаты работ [1-2] и комментарии к ним в монографиях [3-5]. Известно, что исследование вопросов многопериодических решений систем D_e -уравнений в частных производных первого порядка с одинаковой главной частью берет свое начало в трудах [6-7]. На их основе дальнейшие некоторые качественные исследования продолжены в работах [8-11].

Ключевые слова: линейная однородная система, дифференциальный оператор, жордановый канонический вид, многопериодическая матрица, главная диагональ, вектор-период.

Сведения об авторах:

Кульжумиева Айман Амангельдиевна - кандидат физико-математических наук, Западно-Казахстанский государственный университет им. М. Утемисова, aiman-80@mail.ru;

Сартабанов Жайшылык Алмаганбетович - доктор физико-математических наук, профессор, Актюбинский региональный государственный университет им. К. Жубанова, sartabanov42@mail.ru

МАЗМУНЫ

Кульжумиева А.А., Сартабанов Ж.А. Сызықты біртекті D_e -жүйелерді жордандық канондық түрге келтіру.....	5
Сайдуллаева Н.С., Кабылбеков К.А., Аширбаев Х.А., Каликулова А.О., Пазылова Д.Т. Matlab бағдарламалар пакетін қолданып «Сыртқы күш әсер еткенде мәжбүрлі тербелістерді есептеу және визуализациялау» компьютерлік зертханалық жұмысты орындауды ұйымдастыру.....	13
Сайдуллаева Н.С., Тагаев Н.С., Пазылова Д.Т., Каликулова А.О. Влияние однократной перегрузки на развитие усталостной трещины.....	22
Жантаев Ж.Ш., Виляев А.В., Серикбаева Э.Б. Солтүстік Тянь-Шаньнің сейсмикалық тәртіп ерекшелігін бағалауда геотермиялық үлгілеуді қолдану.....	26
Гордиенко Г.И., Яковец А.Ф., Литвинов Ю.Г. Ионосфералақы F-аймақтың биіктігін бағалау әдістерін салыстыру.....	35
Яковец А.Ф., Гордиенко Г.И., Крюков С.В., Жумабаев Б.Т., Литвинов Ю.Г. Электрондық концентрацияның ионосфераның F2-қабатының максималындағы күнделікті өзгеруі.....	44
Яковец А.Ф., Гордиенко Г.И., Жумабаев Б.Т., Литвинов Ю.Г., Абдрахманов Н. Максимум F2-қабатының түнгі көбеюлерінің жұқа құрылымы.....	50
Васильев И.В., Жұмбаев Б.Т. Жердің электрлік өрісінің қалыптасуына гравитациялық күшінің әсері.....	55
Козин И.Д., Федулina И.Н. Радиофизика есептерін шешудегі вакуум – орта.....	60
Козин И.Д., Федулina И.Н. Радиотолқынның қабылдағыш антеннаға әсері.....	66
Жантаев Ж.Ш., Стихарный А.П., Виляев А.В. Жердің қазіргі заманғы қозғалысының GPS бақылауындағы уақыттық қатарларының кедергісін сүзу алгоритмі.....	71
Батрышев Д.Ф., Ерланұлы Е., Рамазанов Т.С., Габдуллин М.Т. Бір қабырғалы көміртекті нанотүтікшелердің құрылымдық және электрондық қасиеттерін BECKE 3-PARAMETER LEE-YANG-PARR (B3LYP) гибрид функционалы негізінде зерттеу.....	75
Серебрянский А. В., Усольцева Л. А., Комаров А. А., Рева И.В. Атмосфералық экстинкцияның лездік мәндері және ауысуы коэффициенттері.....	84
Бақтыбаев Қ., Бақтыбаев М.К., Наукенов Д.Д., Далелханкызы А. Өзара әрекеттесуші бозондар моделінің микроскоптық негіздемесі және ядролық теориядағы жалпыланған квазиспиндік формализм.....	91
Бапаев К.Б., Слэмжанова С.С. Айырымдық-динамикалық жүйелердің орнықтылығы.....	101
Иманбаева А.Б., Шалданбаев А.Ш., Копжасарова А.А. Коэффициенттері тұрақты кәдімгі дифференциалдық теңдеулер системасының сингуляр әсерленген Коши есебін спектралдік әдіспен шешу.....	112
Копжасарова А.А., Шалданбаев А.Ш., Иманбаева А.Б. Ұқсастық әдісі бойынша, сингуляр әсерленген Кошидің есебін шешу.....	127
Косов В.Н., Жакебаев Д.Б., Федоренко О.В. Изотермиялық диффузия кезіндегі тік каналдардағы үшкомпонентті газдар қоспаларында пайда болатын конвективтік қозғалыстардың сандық талдауы.....	134
Мырзақұл Ш.Р., Белисарова Ф.Б., Мырзақұл Т.Р., Мырзакулов К.Р. Старобинский моделінің негізіндегі F-эссенция динамикасы	143
Мамырбаев О.Ж., Мухсина Қ.Ж. Мәтін үндесітілігін анықтауға арналған қолданыстағы жүйелерді талдау.....	149
Омашова Г.Ш., Спабекова Р., Қабылбеков К.А., Саидахметов П.А., Абдрахманова Х.К., Аширбаев Х.А. Физикалық құбылыстарды компьютерлік моделдеуде MATLAB жүйесін қолдану.....	156

СОДЕРЖАНИЕ

Кульжумиева А.А., Сартабанов Ж.А. Приведение линейных однородных D_e -систем к жордановому каноническому виду.....	5
Сайдуллаева Н.С., Кабылбеков К.А., Аширбаев Х.А., Каликулова А.О., Пазылова Д.Т. Организация выполнения компьютерной лабораторной работы «Расчет и визуализация вынужденных колебаний при наличии внешней силы» с применением пакета программ Matlab.....	13
Сайдуллаева Н.С., Тагаев Н.С., Пазылова Д.Т., Каликулова А.О. Влияние однократной перегрузки на развитие усталостной трещины.....	22
Жантаев Ж.Ш., Виляев А.В., Серикбаева Э.Б. Применение геотермического моделирования в оценке особенностей сейсмического режима Северного Тянь-Шаня.....	26
Гордиенко Г.И., Яковец А.Ф., Литвинов Ю.Г. Сравнение методов оценки высоты максимума F-области ионосферы.....	35
Яковец А.Ф., Гордиенко Г.И., Крюков С.В., Жумабаев Б.Т., Литвинов Ю.Г. День ото дня вариации электронной концентрации в максимуме F2-слоя ионосферы.....	44
Яковец А.Ф., Гордиенко Г.И., Жумабаев Б.Т., Литвинов Ю.Г., Абдрахманов Н. Тонкая структура ночных увеличений в максимуме F2-слоя.....	50
Васильев И.В., Жумабаев Б.Т. Влияние гравитации на формирование электрического поля земли.....	55
Козин И.Д., Федулина И.Н. Вакуум – среда в решении задач радиофизики.....	60
Козин И.Д., Федулина И.Н. Воздействие радиоволны на приёмную антенну.....	66
Жантаев Ж.Ш., Стихарный А.П., Виляев А.В. Алгоритм фильтрации помех временных рядов GPS мониторинга современных движений земной поверхности	71
Батрышев Д.Г., Ерланулы Е., Рамазанов Т.С., Габдуллин М.Т. Исследование структурных и электронных свойств одностенных углеродных нанотрубок на основе гибридного функционала bescke 3-PARAMETER LEE-YANG-PARR (V3LYP).....	75
Серебрянский А. В., Усольцева Л. А., Комаров А. А., Рева И. В. Коэффициенты перехода и мгновенные значения атмосферной экстинкции.....	84
Бактыбаев К., Бактыбаев М.К., Наукенов Д.Д., Далелханкызы А. Микроскопическое обоснование модели взаимодействующих бозонов и обобщенный квазиспиновый формализм в теории ядра	91
Бапаев К.Б., Сламжанова С.С. Об устойчивости разностно – динамических систем.....	101
Иманбаева А.Б., Копжасарова А.А., Шалданбаев А.Ш. Асимптотическое разложение решения сингулярно возмущенной задачи Коши для системы обыкновенных дифференциальных уравнений с постоянными коэффициентами.....	112
Копжасарова А.А., Шалданбаев А.Ш., Иманбаева А.Б. Решение сингулярно возмущенной задачи Коши методом подобия.....	127
Косов В.Н., Жакебаев Д.Б., Федоренко О.В. Численный анализ конвективных движений, возникающих при изотермической диффузии в вертикальных каналах в трехкомпонентных газовых смесях.....	134
Мырзакул Ш.Р., Белисарова Ф.Б., Мырзакул Т.Р., Мырзакулов К.Р. Динамика F-эссенции в рамках модели старобинского	143
Мамырбаев О.Ж., Мухсина Қ.Ж. Анализ существующих систем для определения тональности текста.....	149
Омашова Г.Ш., Спабекова Р., Кабылбеков К.А., Саидахметов П.А., Абдрахманова Х.К., Аширбаев Х.А. Использование системы MATLAB при компьютерном моделировании физических процессов.....	156

CONTENTS

<i>Kulzhumiyeva A.A., Sartabanov Zh.A.</i> Reduction of linear homogeneous D_e -systems to the jordan canonical form.....	5
<i>Saidullayeva N.S., Kabyzbekov K.A., Ashirbaev Kh.A., Kalikulova A.O., Pazylova D.T.</i> Organization of computer lab work "Calculation and visualization of forced oscillations in the presence of an external force" with the use of the software package Matlab.....	13
<i>Saidullayeva N.S., Tagaev N.S., Pazylova D.T., Kalikulova A.O.</i> Effect of single overload on the development of a fatigue crack.....	22
<i>Zhantaev Zh.Sh., Vilyayev A.V., Serikbaeva E.B.</i> The application of geothermal modeling in the assessment of the features of the seismic regime of the Northern Tien Shan.....	26
<i>Gordienko G.I., Yakovets A.F., Litvinov Yu.G.</i> Comparison of the methods for estimating the hight of the maximum of th F region of the ionosphere.....	35
<i>Yakovets A.F., Gordienko G.I., Kryukov S.V., Zhumabayev B.T., Litvinov Yu.G.</i> Day-to-day variability of electron concentration n the ionospheric $F2$ layer maximum.....	44
<i>Yakovets A.F., Gordienko G.I., Zhumabayev B.T., Litvinov Yu.G., Abdrakhmanov N.</i> Fine structure of nighttime enhancements of the electron concentration in the $F2$ layer maximum	50
<i>Vassilyev I.V., Zhumabayev B.T.</i> Influence of gravitation on formation of the electric field of the earth.....	55
<i>Kozin I.D., Fedulina I.N.</i> Vacuum - environment in the decision of radio physics problems.....	60
<i>Kozin I.D., Fedulina I.N.</i> Radio-wave action on the receiving antenna.....	66
<i>Zhantaev Zh.Sh., Stikharny A.P., Vilyayev A.V.</i> The algorithm for filtering the errors of time series GPS monitoring of factual movements of the earth's surface.....	71
<i>Batryshev D.G., Yerlanuly Ye., Ramazanov T.S., Gabdullin M.T.</i> Investigation of structural and electronic properties of single-walled carbon nanotubes on the basis of a hybrid functional becke 3-parameter LEE-YANG-PARR (B3LYP).....	75
<i>Serebryanskiy A., Usoltseva L., Komarov A., Reva I.</i> The trasformation coefficients and instantaneous values of atmospheric extinction.....	84
<i>Baktybaev K., Baktybaev M.K., Naukenov D.D., Dalelkhankyzy A.</i> Microscopic justification of the model of interacting bosons and a generalizedquasispin formalism in the theory of the nuclei.....	91
<i>Bapayev K.B., Slamzhanova S.S.</i> On stability of difference-dynamical systems	101
<i>Imanbayeva A.B., Shaldanbayev A.Sh., Kopzhasarova A.A.</i> Asymptotic decomposition the decision is singular the indignant task of Cauchy for the system of the ordinary differential equations with constant coefficients.....	112
<i>Kopzhasarova A.A., Shaldanbayev A.Sh., Imanbayeva A.B.</i> The decision is singular the indignant task of Cauchy by a similarity method.....	127
<i>Kossov V.N., Zhakebaev D.B., Fedorenko O.V.</i> Numerical analysis of convective motions occurring under isothermal Diffusion in the vertical channels in ternary gaseous mixtures.....	134
<i>Myrzakul S.R., Belisarova F.B., Myrzakul T.R., Myrzakulov K.R.</i> Dynamics of F-essence in frame of the starobinsky model.....	143
<i>Mamyrbayev O.Zh., Muhsina K.Zh.</i> Analysis of existing systems for determination of tonnity of text.....	149
<i>Omashova G. Sh., Spabekova R., Kabyzbekov K. A., Saidahmetov P. A., Abdrakhmanova H. K., Ashirbaev H. A.</i> The use of the system MATLAB in the compyter simulation of physical processes.....	156

**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>

ISSN 2518-1726 (Online), ISSN 1991-346X (Print)

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

Подписано в печать 25.09.2017.
Формат 60x88¹/₈. Бумага офсетная. Печать – ризограф.
11 п.л. Тираж 300. Заказ 5.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-18, 272-13-19