

ЎзР ФА В.И. Романовский номидаги Математика институти
Математика институти Бухоро бўлинмаси

**ДИФФЕРЕНЦИАЛ ТЕНГЛАМАЛАР ВА
АНАЛИЗНИНГ ТУРДОШ МАСАЛАЛАРИ**

хорижий олимлар иштирокидаги илмий конференцияси

МАТЕРИАЛЛАРИ

Бухоро, Ўзбекистон, 04–05 ноябр, 2021 йил

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Институт Математики имени В.И. Романовского АН РУз
Бухарское отделение института Математики

ТЕЗИСЫ ДОКЛАДОВ

Республиканской научной конференции с участием зарубежных ученых

**ДИФФЕРЕНЦИАЛЬНЫЕ УРАВНЕНИЯ
И РОДСТВЕННЫЕ ПРОБЛЕМЫ АНАЛИЗА**

Бухара, Узбекистан, 04–05 ноябрь, 2021 год

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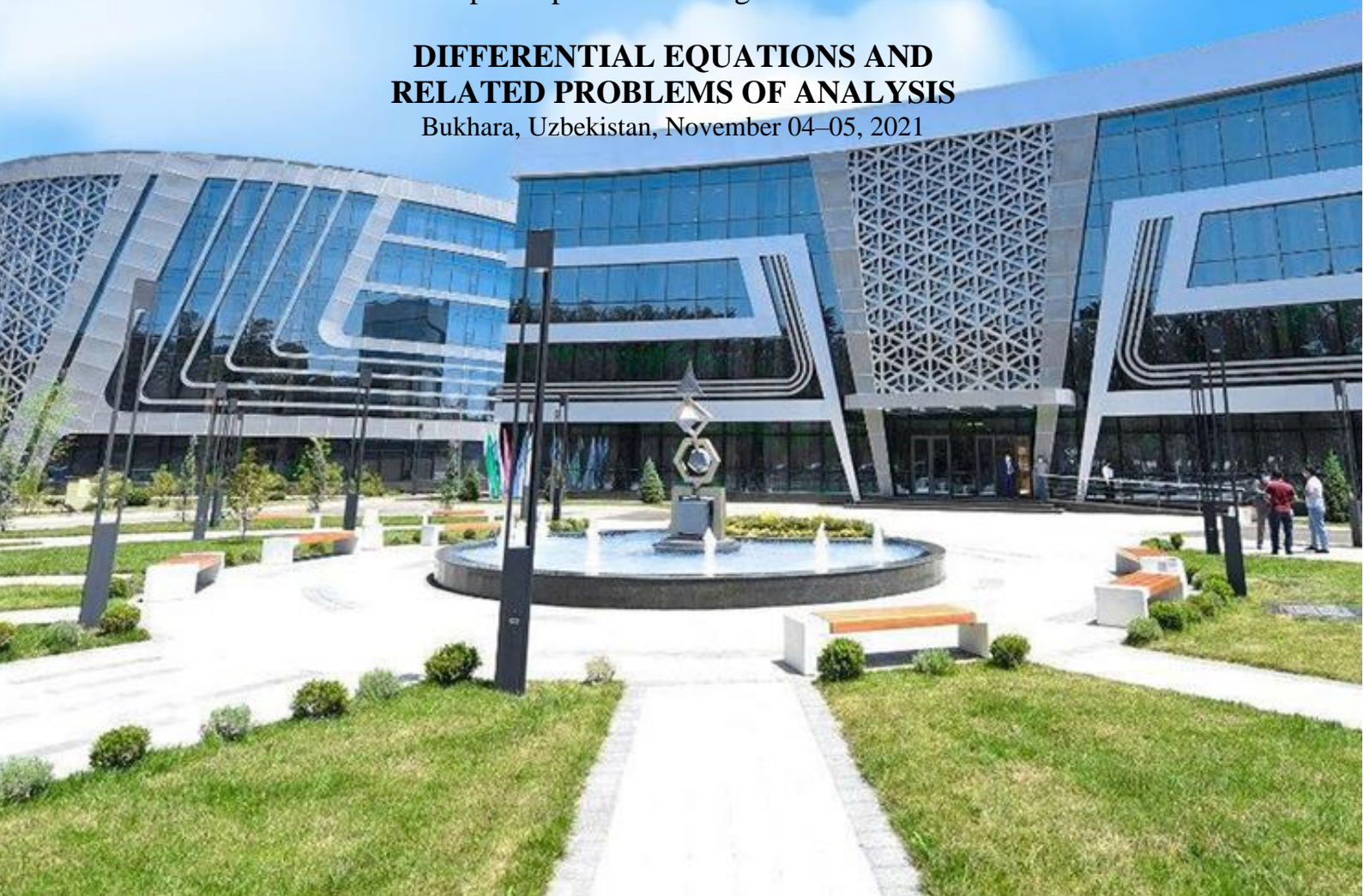
Institute of Mathematics named after V.I. Romanovskiy at the
AS of Uzbekistan
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ABSTRACTS

of the Republican Scientific Conference with the
participation of foreign scientists

**DIFFERENTIAL EQUATIONS AND
RELATED PROBLEMS OF ANALYSIS**

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**ESTIMATES FOR THE BOUNDS OF THE ESSENTIAL SPECTRUM OF A
2 × 2 OPERATOR MATRIX**

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We study the essential spectrum of the 2×2 operator matrix of the form

$$\mathcal{A}_\mu := \begin{pmatrix} A_{11} & \mu A_{12} \\ \mu A_{12}^* & A_{22} \end{pmatrix}, \quad \mu > 0$$

acting in the Hilbert space

$$\mathcal{H} := \mathcal{H}_1 \oplus \mathcal{H}_2$$

with $\mathcal{H}_1 := L^2(\mathbb{T}^d)$ and $\mathcal{H}_2 := L^2_{\text{sym}}((\mathbb{T}^d)^2)$. Here \mathbb{T}^d is the d -dimensional torus, the cube $(-\pi, \pi]^d$ with appropriately identified sides equipped with its Haar measure and $L^2_{\text{sym}}((\mathbb{T}^d)^2)$ stands for the subspace of $L^2((\mathbb{T}^d)^2)$ consisting of symmetric functions (with respect to the two variables). The matrix entries $A_{ij} : \mathcal{H}_j \rightarrow \mathcal{H}_i$, $i \leq j$, $i, j = 1, 2$, are given by

$$\begin{aligned} (A_{11}f_1)(k_1) &= w_1(k_1)f_1(k_1), & (A_{12}f_2)(k_1) &= \int_{\mathbb{T}^d} f_2(k_1, t)dt, \\ (A_{22}f_2)(k_1, k_2) &= w_2(k_1, k_2)f_2(k_1, k_2), & f_i \in \mathcal{H}_i, & \quad i = 1, 2. \end{aligned}$$

Here $\mu > 0$ is a coupling constant, the functions $w_1(\cdot)$ and $w_2(\cdot, \cdot)$ have the form

$$w_1(k_1) := \varepsilon(k_1) + \gamma, \quad w_2(k_1, k_2) := \varepsilon(k_1) + \varepsilon\left(\frac{1}{2}(k_1 + k_2)\right) + \varepsilon(k_2)$$

with $\gamma \in \mathbb{R}$ and the dispersion function $\varepsilon(\cdot)$ is defined by

$$\varepsilon(k_1) := \sum_{i=1}^d (1 - \cos k_1^{(i)}), \quad k_1 = (k_1^{(1)}, \dots, k_1^{(d)}) \in \mathbb{T}^d,$$

Let $H_0 := \mathbb{C}$. To study the spectral properties of the operator \mathcal{A}_μ , we introduce the following auxiliary family of bounded self-adjoint operators (generalized Friedrichs models) $\mathcal{A}_\mu(k)$, $k \in \mathbb{T}^d$, which acts in $\mathcal{H}_0 \oplus \mathcal{H}_1$ as 2×2 operator matrices

$$\mathcal{A}_\mu(k) := \begin{pmatrix} A_{00} & \frac{\mu}{\sqrt{2}}A_{01} \\ \frac{\mu}{\sqrt{2}}A_{01}^* & A_{11}(k) \end{pmatrix},$$

with matrix elements

$$\begin{aligned} A_{00}f_0 &= \gamma f_0, & (A_{01}f_1) &= \int_{\mathbb{T}^d} f_1(t)dt, \\ (A_{11}(k)f_1)(k_1) &= E_k(k_1)f_1(k_1), & f_i &\in \mathcal{H}_i, \quad i = 0, 1, \end{aligned}$$

where the function $E_k(\cdot)$ is defined by

$$E_k(k_1) := \varepsilon\left(\frac{1}{2}(k + k_1)\right) + \varepsilon(k_1).$$

To simplify the notation we set

$$\Lambda_\mu := \bigcup_{k \in \mathbb{T}^d} (\varepsilon(k) + \sigma_{\text{disc}}(\mathcal{A}_\mu(k))), \quad \Sigma_\mu := [0; 6d] \cup \Lambda_\mu.$$

Let

$$\begin{aligned} a_\mu^{\min} &:= \min \Sigma_\mu, & a_\mu^{\max} &:= \max \Sigma_\mu; \\ \mu_l^0(\gamma) &:= \sqrt{\gamma} \left(\int_{\mathbb{T}^d} \frac{dt}{\varepsilon(t/2) + \varepsilon(t)} \right)^{-1/2} & \text{for } \gamma > 0; \\ \mu_r^0(\gamma) &:= \sqrt{4d - \gamma} \left(\int_{\mathbb{T}^d} \frac{dt}{\varepsilon(t/2) + \varepsilon(t)} \right)^{-1/2} & \text{for } \gamma < 4d. \end{aligned}$$

We can now state the detailed information on bounds of the essential spectrum of \mathcal{A}_μ for the case $d \geq 3$ with respect to the spectral parameters $\gamma \in \mathbb{R}$ and $\mu > 0$ [1]:

Case I. Let $\gamma \leq 0$. Then for any $\mu > 0$ we have

$$a_\mu^{\min} = \min \Lambda_\mu \leq \varepsilon(\bar{0}) + E_\mu^{(l)} < 0;$$

moreover,

- $a_\mu^{\max} = 6d$, if $\mu \in (0; \mu_r^0(\gamma)]$;
- $a_\mu^{\max} = \max \Lambda_\mu \geq \varepsilon(\bar{\pi}) + E_\mu^{(r)} > 6d$, if $\mu > \mu_r^0(\gamma)$.

Case II. Let $\gamma \in (0; 2d]$. Then

- $a_\mu^{\min} = 0$ and $a_\mu^{\max} = 6d$, if $\mu \in (-\infty; \mu_l^0(\gamma)]$;
- $a_\mu^{\min} = \min \Lambda_\mu \leq \varepsilon(\bar{0}) + E_\mu^{(l)} < 0$ and $a_\mu^{\max} = 6d$, if $\mu \in (\mu_l^0(\gamma); \mu_r^0(\gamma)]$;
- $a_\mu^{\min} = \min \Lambda_\mu \leq \varepsilon(\bar{0}) + E_\mu^{(l)} < 0$ and $a_\mu^{\max} = \max \Lambda_\mu \geq \varepsilon(\bar{\pi}) + E_\mu^{(r)} > 6d$, if $\mu \in (\mu_r^0(\gamma); +\infty)$.

Case III. Let $\gamma \in (2d; 4d)$. Then

- $a_\mu^{\min} = 0$ and $a_\mu^{\max} = 6d$, if $\mu \in (-\infty; \mu_r^0(\gamma)]$;
- $a_\mu^{\min} = 0$ and $a_\mu^{\max} = \max \Lambda_\mu \geq \varepsilon(\bar{\pi}) + E_\mu^{(r)} > 6d$, if $\mu \in (\mu_r^0(\gamma); \mu_l^0(\gamma)]$;
- $a_\mu^{\min} = \min \Lambda_\mu \leq \varepsilon(\bar{0}) + E_\mu^{(l)} < 0$ and $a_\mu^{\max} = \max \Lambda_\mu \geq \varepsilon(\bar{\pi}) + E_\mu^{(r)} > 6d$, if $\mu \in (\mu_l^0(\gamma); +\infty)$.

Case IV. Let $\gamma \geq 4d$. Then for any $\mu > 0$ we have $a_\mu^{\max} = 6d$; moreover,

- $a_\mu^{\min} = 0$, if $\mu \in (0; \mu_l^0(\gamma)]$;
- $a_\mu^{\min} = \min \Lambda_\mu \leq \varepsilon(\bar{0}) + E_\mu^{(l)} < 0$, if $\mu > \mu_l^0(\gamma)$.

All assertions mentioned above play crucial role in the study of the number of discrete eigenvalues of \mathcal{A}_μ lying outside of its essential spectrum.

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PERIODIC GROUND STATES CORRESPONDING TO SUBGROUPS OF INDEX THREE FOR THE ISING MODEL ON THE CAYLEY TREE OF ORDER THREE

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The Cayley tree Γ^k of order $k \geq 1$ is an infinite tree, i.e., a graph without cycles, from each vertex of which exactly $k + 1$ edges issue (see [1]). Let $\Gamma^k = (V, L, i)$, where V is the set of vertices of Γ^k , L is the set of edges of Γ^k and i is the incidence function associating each edge $l \in L$ with its endpoints $x, y \in V$. If $i(l) = \{x, y\}$, then x and y are called *nearest neighboring vertices*, and we write $l = \langle x, y \rangle$. The distance $d(x, y)$, $x, y \in V$ on the Cayley tree is the shortest path from x to y .

For the fixed $x^0 \in V$ (as usual, x^0 is called a root of the tree) we set

$$W_n = \{x \in V \mid d(x, x^0) = n\}.$$

We write $x < y$ if the path from x^0 to y goes through x and $|x| = d(x, x^0)$, $x \in V$.

It is known that there exists a one-to-one correspondence between the set V of vertices of the Cayley tree of order $k \geq 1$ and the group G_k of the free products of $k + 1$ cyclic groups $\{e, a_i\}$, $i = 1, \dots, k + 1$ of the second order (i.e. $a_i^2 = e$, $a_i \neq e$) with generators a_1, a_2, \dots, a_{k+1} .

At first, we give main definitions and facts about the Ising model. We consider models where the spin takes values in the set $\Phi = \{-1, 1\}$. For $A \subseteq V$ a spin *configuration* σ_A on A is defined as a function $x \in A \rightarrow \sigma_A(x) \in \Phi$; the set of all configurations is denoted by $\Omega_A = \Phi^A$. Put $\Omega = \Omega_V$, $\sigma = \sigma_V$ and $-\sigma_A = \{-\sigma_A(x), x \in A\}$. Define a *periodic configuration* as a configuration $\sigma \in \Omega$ which is invariant under cosets of a subgroup $G_k^* \subset G_k$ of finite index.

The index of a subgroup is called the *period of the corresponding periodic configuration*. A configuration that is invariant with respect to all cosets is called *translation-invariant*.

Let $G_k/G_k^* = \{H_1, \dots, H_r\}$ be a family of cosets, where G_k^* is a subgroup of index $r \geq 1$. We consider model which its spins take values in the set $\Phi = \{-1, 1\}$.

The Ising model with competing interactions has the form

$$H(\sigma) = J_1 \sum_{\langle x, y \rangle \in L} \sigma(x)\sigma(y) + J_2 \sum_{\substack{x, y \in V: \\ d(x, y) = 2}} \sigma(x)\sigma(y),$$

where $J = (J_1, J_2) \in \mathbb{R}^2$ are coupling constants and $\sigma \in \Omega$.

Let M be the set of unit balls with vertices in V . We call the restriction of a configuration σ to the ball $b \in M$ a *bounded configuration* σ_b .

Define the energy of a ball b for configuration σ by

$$U(\sigma_b) \equiv U(\sigma_b, J) = \frac{1}{2} J_1 \sum_{\langle x, y \rangle \in L} \sigma(x)\sigma(y) + J_2 \sum_{d(x, y) = 2} \sigma(x)\sigma(y), \quad x, y \in b,$$

Mundarija

I SHO‘BA: MATEMATIK ANALIZ

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