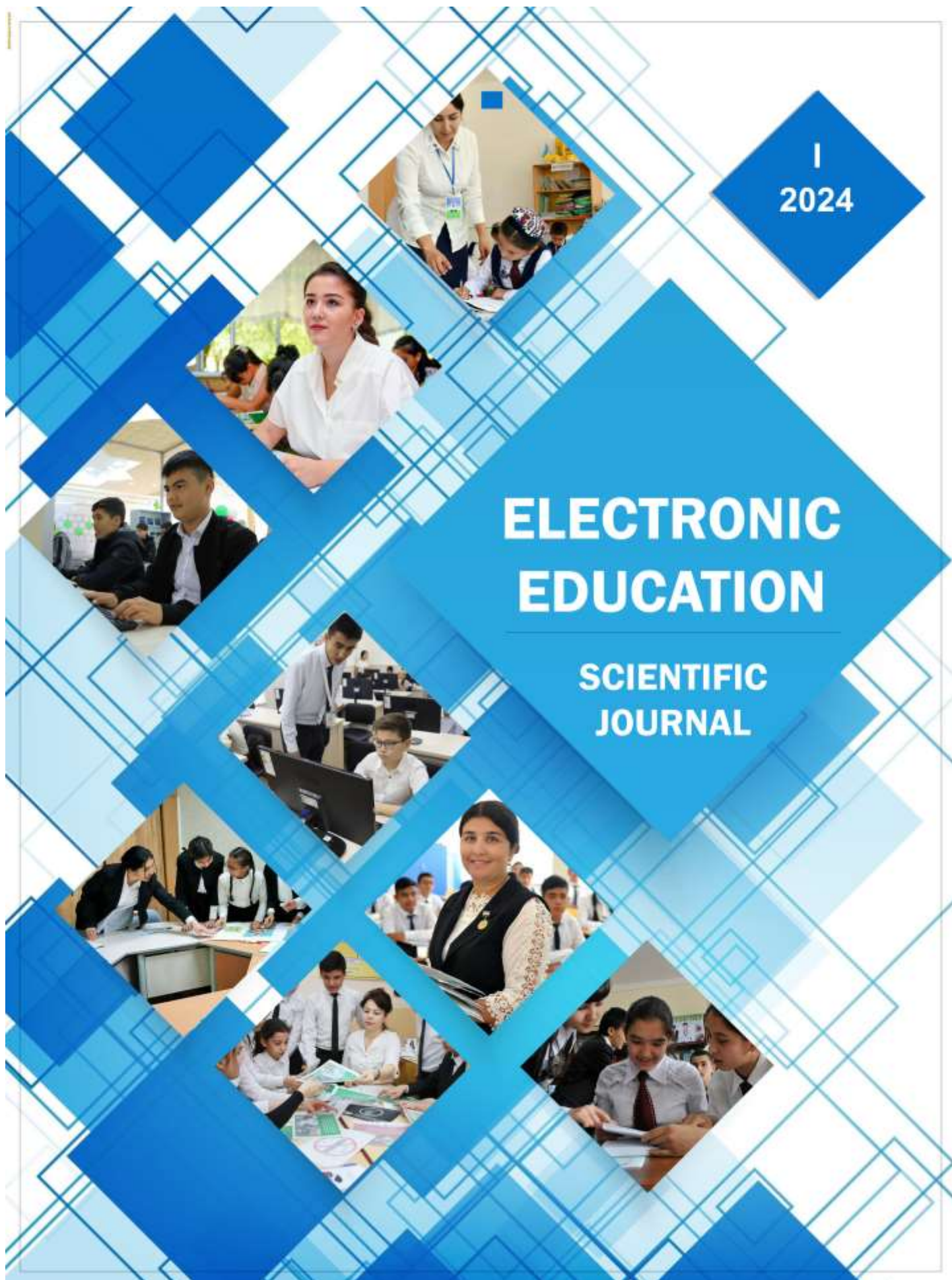


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MUNDARIJA

Aniq fanlarda axborot texnologiyalari

Davlatov Sh.O., Achilov I. A. <i>TO‘G‘RI TO‘RTBURCHAKLI SOHADA ISSIQLIK TENGLAMASINI TO‘R METODI BILAN SONLI YECHISH</i>	10
Norov A. M., Murodov Sh. A., Abdullayev Sh. Sh., Sa'dullayeva M. L. <i>SILLABEMA MODELINING TURKIY TILLARGA TATBIQI (QIRG‘IZ TILI MISOLIDA)</i>	21
Ro‘ziyev R. A. <i>BO‘LAJAK O‘QITUVCHILARNI TAYYORLASHDA RAQAMLI TEXNOLOGIYALARNING DIDAKTIK IMKONIYATI</i>	32
Toxirov F. J. <i>TALABALARNING MOBIL ILOVALARNI YARATISHGA OID KOMPETENTLIGINI RIVOJLANTIRISHDAGI MUAMMOLAR</i>	41
Absalamov T. T. <i>ELEKTRON TA‘LIMDA TALABA VA O‘QITUVCHINING O‘ZARO MUNOSABATLARIDA SUN‘IY INTELEKTNING O‘RNI</i>	48
Mirsanov U. M., Jo‘rakulov T. T., Sadritdinova D. A. <i>BO‘LAJAK MATEMATIK VA INFORMATIKA O‘QITUVCHILARINING KASBIY KOMPETENTLIGINI RIVOJLANTIRISHDA BULUTGA ASOSLANGAN TA‘LIM MUHITLARIDAN FOYDALANISH</i>	60
Maxsetova M. M. <i>UMUMIY O‘RTA TA‘LIM MAKTAB O‘QUVCHILARINI KOMPYUTER GRAFIKASIGA OID KOMPETENSIYALARINI SHAKLLANTIRISH MODEL</i>	70
Xalikov A. T. <i>O‘QUVCHILARNING FRILANSERLIKKA OID KOMPETENSIYALARINI SHAKLLANTIRISHDA AXBOROT-TA‘LIM MUHITLARINING AMALIY SAMARADORLIGI</i>	80
Djumabaev K. N. <i>C++ TILINI O‘QITISH MUAMMOLI TA‘LIMNING TEXNOLOGIYASIDAN FOYDALANISH USULI</i>	90
Xamroyev U. N. <i>PEDAGOGIKA OLIY TA‘LIM MUASSASALARI TALABALARINING ALGORITMLASHGA OID KOMPETENTLIGINI RIVOJLANTIRISH MODEL</i>	101
Jumayeva D. N. <i>KASB-HUNAR MAKTABI O‘QUVCHILARINING MUSTAQIL TA‘LIMINI TASHKIL ETISH USULI</i>	111
Ruziyev R. A., Donayev N. Y. <i>TA‘LIM JARAYONIDA BULUTLI TEXNOLOGIYALARDAN FOYDALANISHNING USLUBIY VA TEXNOLOGIK JIHATLARI</i>	119

Qulmurodov I. E.

UMUMIY O‘RTA TA’LIM MAKTAB O‘QUVCHILARNING GEOMETRIK
TASAVVURLARINI SHAKLLANTIRISHDA UCH O‘LCHOVLI O‘QUV VOSITALARNING
IMKONIYATLARI 127

Esanbayev B. I.

TALABALARNI FRAKTAL GRAFIKAGA OID KOMPETENTLIGINI
RIVOJLANTIRISHNING PEDAGOGIK SHARTLARI 136

Juraboyev A. J.

O‘QUVCHILARNING DARSDAN TASHQARI O‘QUV FAOLIYATIDA KOMPYUTERNING
TEXNIK VA DASTURIY TA’MINOTIGA OID KOMPETENSIYALARINI SHAKLLANTIRISH 146

Ruziyeva D. R.

TA’LIM JARAYONINING SAMARALILIGINI OSHIRISHDA KOMPYUTER O‘QUV
DASTURIY TA’MINOTINING IMKONIYATLARI 155

Mirsanov J. M.

UMUMIY O‘RTA TA’LIM MAKTAB O‘QUVCHILARINI DASTURLASHGA OID
ALGORITMIK FIKRLASHINI RIVOJLANTIRISHDA UCHLIK METODDAN
FOYDALANISH 164

Tabiiy fanlarda axborot texnologiyalari

Abralov O Sobirovich

BO‘LAJAK BIOLOGIYA O‘QITUVCHILARINI TAYYORLASHDA ARALASH TA’LIM
TEXNOLOGIYASINING AMALIY SAMARADORLIGI 171

Jurayeva D. Y.

BIOLOGIYA O‘QITISH METODIKASI FANIDAN MUSTAQIL TA’LIMNI BULUTLI
TEXNOLOGIYALAR ASOSIDA TASHKIL ETISHNING SAMARADORLIGINI ANIQLASHDA
PEDAGOGIK TAJRIBA-SINOV USULLARI VA TAHLILLARI 179

СОДЕРЖАНИЕ

Информационные технологии в точных науках

Давлатов Ш. О., Ачилов И. А. ЧИСЛЕННОЕ РЕШЕНИЕ УРАВНЕНИЯ ТЕПЛОПРОВОДНОСТИ МЕТОДОМ СЕТКА НА ПРЯМОУГОЛЬНОЙ ОБЛАСТИ	10
Норов А.М., Муродов Ш.А., Абдуллаев Ш. Ш., Садуллаева М. Л. ПРИМЕНЕНИЕ МОДЕЛИ СИЛЛАБЕМЫ К ТУРЕЦКИМ ЯЗЫКАМ (НА ПРИМЕРЕ КЫРГЫЗСКОГО ЯЗЫКА)	21
Рузиев Р. А. ДИДАКТИЧЕСКИЕ ВОЗМОЖНОСТИ ЦИФРОВЫХ ТЕХНОЛОГИЙ В ПОДГОТОВКЕ БУДУЩИХ УЧИТЕЛЕЙ	32
Тохиров Ф. Д. ПРОБЛЕМЫ РАЗВИТИЯ КОМПЕТЕНТНОСТИ ПО СОЗДАНИЮ МОБИЛЬНЫХ ПРИЛОЖЕНИЙ СТУДЕНТОВ	41
Абсаламов Т. Т. ВЛИЯНИЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА О ВЗАИМОДЕЙСТВИИ ОБУЧАЮЩЕГОСЯ И ПРЕПОДАВАТЕЛЯ В ЭЛЕКТРОННОМ ОБУЧЕНИИ	48
Мирсанов У. М., Журакулов Т. Т., Садритдинова Д.А. ИСПОЛЬЗОВАНИЕ ОБЛАЧНЫХ ОБРАЗОВАТЕЛЬНЫХ СРЕД ДЛЯ РАЗВИТИЯ ПРОФЕССИОНАЛЬНОЙ КОМПЕТЕНТНОСТИ БУДУЩИХ УЧИТЕЛЕЙ МАТЕМАТИКИ И ИНФОРМАТИКИ	60
Махсетова М. М. МОДЕЛЬ ФОРМИРОВАНИЯ КОМПЕТЕНЦИЙ УЧАЩИХСЯ ОБЩЕОБРАЗОВАТЕЛЬНЫХ ШКОЛ ПО КОМПЬЮТЕРНОЙ ГРАФИКЕ	70
Халиков А. Т. ПРАКТИЧЕСКАЯ ЭФФЕКТИВНОСТЬ ИНФОРМАЦИОННО-ОБРАЗОВАТЕЛЬНОЙ СРЕДЫ В ФОРМИРОВАНИИ ФРИЛАНСЕРСКИХ КОМПЕТЕНЦИЙ УЧАЩИХСЯ	80
Джумабаев К. Н. ОБУЧЕНИЕ ЯЗЫКУ C++ С ИСПОЛЬЗОВАНИЕМ ТЕХНОЛОГИИ ПРОБЛЕМНОГО ОБУЧЕНИЯ	90
Хамроев У. Н. МОДЕЛЬ РАЗВИТИЯ АЛГОРИТМИЧЕСКОЙ КОМПЕТЕНТНОСТИ СТУДЕНТОВ ПЕДАГОГИЧЕСКИХ ВУЗОВ	101
Жумаева Д. Н. МЕТОДИКА ОРГАНИЗАЦИИ САМОСТОЯТЕЛЬНОГО ОБУЧЕНИЯ УЧАЩИХСЯ В ПРОФЕССИОНАЛЬНЫХ ШКОЛАХ	111
Рузиев Р. А., Донаев Н. Ю. МЕТОДОЛОГИЧЕСКИЕ И ТЕХНОЛОГИЧЕСКИЕ АСПЕКТЫ ИСПОЛЬЗОВАНИЯ ОБЛАЧНЫХ ТЕХНОЛОГИЙ В ОБРАЗОВАТЕЛЬНОМ ПРОЦЕССЕ	119

Гулмуродов И.Э. ВОЗМОЖНОСТИ ТРЕХМЕРНЫХ ОБРАЗОВАТЕЛЬНЫХ СРЕДСТВ В ФОРМИРОВАНИИ ГЕОМЕТРИЧЕСКОГО ВООБРАЖЕНИЯ УЧАЩИХСЯ ОБЩЕОБРАЗОВАТЕЛЬНЫХ ШКОЛЫ	127
Эсанбаева Б.Х. ПЕДАГОГИЧЕСКИЕ УСЛОВИЯ РАЗВИТИЯ КОМПЕТЕНЦИИ СТУДЕНТОВ ПО ФРАКТАЛЬНОЙ ГРАФИКЕ	136
Джурабоев А. Д. ФОРМИРОВАНИЕ КОМПЕТЕНЦИЙ СТУДЕНТОВ В ОБЛАСТИ ТЕХНИЧЕСКОГО И ПРОГРАММНОГО ОБЕСПЕЧЕНИЯ КОМПЬЮТЕРА ВО ВНЕУЧЕБНОЙ ОБРАЗОВАТЕЛЬНОЙ ДЕЯТЕЛЬНОСТИ	146
Рузиева Д. Р. ВОЗМОЖНОСТИ КОМПЬЮТЕРНОГО ОБРАЗОВАТЕЛЬНОГО ПРОГРАММНОГО ОБЕСПЕЧЕНИЯ В ПОВЫШЕНИИ ЭФФЕКТИВНОСТИ ОБРАЗОВАТЕЛЬНОГО ПРОЦЕССА	155
Мирсанов Д. М. ИСПОЛЬЗОВАНИЕ МЕТОДА ТРИНИТИ В РАЗВИТИИ АЛГОРИТМИЧЕСКОГО МЫШЛЕНИЯ О ПРОГРАММИРОВАНИИ УЧАЩИХСЯ ОБЩЕЙ СРЕДНЕЙ ШКОЛЬНИКА	164

Информационные технологии в естественных науках

Абралов О. С. ПРАКТИЧЕСКАЯ ЭФФЕКТИВНОСТЬ СМЕШАННОЙ ОБРАЗОВАТЕЛЬНОЙ ТЕХНОЛОГИИ В ПОДГОТОВКЕ БУДУЩИХ УЧИТЕЛЕЙ БИОЛОГИИ	171
Джуроева Д. Ю. ПЕДАГОГИЧЕСКИЕ ЭКСПЕРИМЕНТАЛЬНЫЕ МЕТОДЫ И АНАЛИЗ ПРИ ОПРЕДЕЛЕНИИ ЭФФЕКТИВНОСТИ ОРГАНИЗАЦИИ САМОСТОЯТЕЛЬНОГО ОБРАЗОВАНИЯ ПО НАУКЕ БИОЛОГИЯ МЕТОДИКА ПРЕПОДАВАНИЯ НА ОСНОВЕ ОБЛАЧНЫХ ТЕХНОЛОГИЙ	179

CONTENT

Information technologies in exact sciences

Davlatov Shakir, Achilov Islam NUMERICAL SOLUTION HEAT EQUATIONS USING THE MESH METHOD ON A RECTANGULAR AREA	10
Norov Abdisait, Muradov Shukrilla, Abdullayev Sherzod, Sadullayeva Maftuna APPLICATION OF SYLLABEMA MODEL TO TURKISH LANGUAGES (IN THE EXAMPLE OF KYRGYZ LANGUAGE)	21
Ruziyev Raup DIDACTIC POSSIBILITY OF DIGITAL TECHNOLOGIES IN TRAINING FUTURE TEACHERS	32
Tokhirov Feruz PROBLEMS OF DEVELOPING COMPETENCE IN CREATING MOBILE APPLICATIONS FOR STUDENTS	41
Absalamov Tolib THE IMPACT OF ARTIFICIAL INTELLIGENCE ON LEARNER-TEACHER INTERACTION IN E-LEARNING	48
Mirsanov Uralboy, Jurakulov Tolib, Sadritdinova Dinora USE OF CLOUD EDUCATIONAL ENVIRONMENTS FOR THE DEVELOPMENT OF PROFESSIONAL COMPETENCE OF FUTURE MATHEMATICS AND COMPUTER SCIENCE TEACHERS	60
Makhsetova Mukhabbat GENERAL SECONDARY EDUCATION MODEL FOR THE FORMATION OF COMPETENCIES OF SCHOOLCHILDREN ON COMPUTER GRAPHICS	70
Khalikov Akbar PRACTICAL EFFECTIVENESS OF THE INFORMATION AND EDUCATIONAL ENVIRONMENT IN FORMING FREELANCING COMPETENCIES OF STUDENTS	80
Dzhumabaev Kuanishbai TEACHING THE C++ LANGUAGE USING PROBLEM-BASED LEARNING TECHNOLOGY	90
Khamroyev Utkir MODEL OF DEVELOPMENT OF ALGORITHMIC COMPETENCE OF STUDENTS OF PEDAGOGICAL UNIVERSITIES	101
Jumayeva Dilafroz METHODS OF ORGANIZING INDEPENDENT EDUCATION FOR VOCATIONAL SCHOOL STUDENTS	111
Ruziyev Raup, Donayev Nuriddin METHODOLOGICAL AND TECHNOLOGICAL ASPECTS OF THE USE OF CLOUD TECHNOLOGIES IN THE EDUCATIONAL PROCESS	119

Kulmurodov Islambek

POSSIBILITIES OF THREE-DIMENSIONAL EDUCATIONAL TOOLS IN FORMING
GENERAL SECONDARY SCHOOL STUDENTS' GEOMETRIC IMAGINATION

127

Esanbayev Bunyod

PEDAGOGICAL CONDITIONS FOR THE DEVELOPMENT OF STUDENTS'
COMPETENCE IN FRACTAL GRAPHICS

136

Juraboev Almir

FORMING THE COMPETENCIES OF STUDENTS IN COMPUTER HARDWARE AND
SOFTWARE EQUIPMENT IN ADDITION TO CLASSROOM LEARNING ACTIVITIES

146

Ruzieva Dilafruz

POSSIBILITIES OF COMPUTER EDUCATIONAL SOFTWARE IN INCREASING THE
EFFECTIVENESS OF THE EDUCATIONAL PROCESS

155

Mirsanov Dzhurabek

USING THE TRINITY METHOD IN THE DEVELOPMENT OF ALGORITHMIC THINKING
ABOUT PROGRAMMING OF GENERAL SECONDARY SCHOOL STUDENTS

164

Information technologies in natural sciences

Abralov Olim

PRACTICAL EFFECTIVENESS OF MIXED EDUCATIONAL TECHNOLOGY IN
TRAINING FUTURE BIOLOGY TEACHERS

171

Juraeva Dildora

PEDAGOGICAL EXPERIMENTAL METHODS AND ANALYSIS IN DETERMINING THE
EFFICIENCY OF ORGANIZING INDEPENDENT EDUCATION IN THE SCIENCE OF
BIOLOGY TEACHING METHODOLOGY BASED ON CLOUD TECHNOLOGIES

179

Aniq fanlarda axborot texnologiyalari

TO‘G‘RI TO‘RTBURCHAKLI SOHADA ISSIQLIK TENGLAMASINI TO‘R METODI BILAN SONLI YECHISH

Davlatov Shokir Oltiboyevich

Qarshi muhandislik-iqtisodiyot instituti dosenti

Achilov Islom Azamatovich

Qarshi muhandislik-iqtisodiyot instituti i katta o‘qituvchi

Annotasiya: *Ushbu maqolada to‘g‘ri to‘rtburchakli sohada issiqlik tenglamasini to‘r metodi bilan sonli yechish algoritmi keltirilgan va shu algoritm asosida Delphi-7 dasturlash muhitida to‘g‘ri to‘rtburchakli sohada issiqlik tenglamasini sonli yechadigan dastur yaratilgan.*

Tayanch so‘zlar: *algoritm, to‘r metodi, sxema, programma, Delphi-7, sistema.*

ЧИСЛЕННОЕ РЕШЕНИЕ УРАВНЕНИЯ ТЕПЛОПРОВОДНОСТИ МЕТОДОМ СЕТКА НА ПРЯМОУГОЛЬНОЙ ОБЛАСТИ

Давлатов Шакир Олтибоевич

Доцент Каршинского инженерно-экономического института

Ачилов Ислам Азаматович

Старший преподаватель Каршинского инженерно-экономического института

Аннотация: *В этой статье приведен алгоритм численного решения уравнения теплопроводности методом сетка на прямоугольной области и на основе этого алгоритма создана программа числена решающая уравнения теплопроводности на прямоугольной области на языке Delphi-7.*

Ключевые слова: *Алгоритм, метод сетка, схема, программа, Delphi-7, система.*

NUMERICAL SOLUTION HEAT EQUATIONS USING THE MESH METHOD ON A RECTANGULAR AREA

Davlatov Shakir

Associate Professor at Karshi Engineering and Economic Institute

Achilov Islam

Senior Lecturer at Karshi Engineering and Economic Institute

Abstract: *Abstract. In this article presents an algorithm for the numerical solution heat equations using the mesh method on a rectangular area and a program in the Delphi-7 language is created based on this algorithm.*

Keywords: *Algorithm, grid method, scheme, program, Delphi-7, sistem.*

Kirish. XXI asr boshida fan va texnikaning, axborot-kommunikasiya texnologiyalarining shiddat bilan rivojlanib borayotganligi globollashuv davrida mamlakatimiz uzluksiz ta’lim tizimida OTMLar talabasining pedagogik salohiyatini axborot texnologiyalariga tayangan holda dasturlash programmalari integrasiyalash asosida kasbiy kompetentligini rivojlantirishning matematika fanining mazmunini hamda o’qitishning metodik tizimini, shakl, usul va vositalarini takomillashtirish zarurati paydo bo’lmoqda.

Mamlakatimizda fundamental fanlarning ilmiy va amaliy tatbiqiga ega bo’lgan matematik fizika, elektrodinamika va amaliy matematika sohalaridagi murakkab masalalarni sonli yechish usullarini qurish va ularning turg’unligini tadqiq etish kabi dolzarb yunalishlariga katta e’tibor qaratilmoqda. Bu borada xususiy hosilali differensial tenglamalar va sistemalariga qo’yilgan chegaraviy masalalarni sonli yechish usullari va algoritmlarini qurishda muhim natijalarga erishildi.

Adabiyotlar tahlili. Jahon tajribasi shuni ko’rsatadiki, gaz dinamikasi, gidrodinamika, elektrodinamika, deformatsiyalanuvchi qattiq jismlar mexanikasi yoki tutash muhitlar mexanikasi va boshqa sohalarining qator muammolarini tadqiq etish differensial tenglamalar va sistemalariga qo’yilgan aralash masalalar yordamida tavsiflanadi. Bunday masalalarni sonli yechish usullari bilan V.A.Ilin, T.Z.Ismagilov, Yu.A.Volkov, V.M.Kovenya, K.Fridriks, A.M.Grishin, A.V.Gulin, A.A.Samarskiy, S.K.Godunov, V.M.Gordiyenko, X.O.Krays, A.N. Malishev, A.M.Bloxin, N.G.Marchuk, R.Sakomota kabi ko’plab olimlar shug’ullanishgan. Ularning ishlarida asosan differensial tenglamalar va sistemalariga qo’yilgan aralash masalalarni ayirmali sxemalar yoki chekli elementlar usullari yordamida sonli yechilgan.

Differensial tenglamalar va sistemalariga qo’yilgan aralash masalani sonli yechish uchun turli xildagi ayirmali sxemalar A.M.Bloxin, R.D.Aloyev, I.Yu.Drujinin, S.S.Abarbanel, A.E.Chertosky, D.A.French, Gui-Qiang Chen, Jian-Guo Liu, J.L.Steger, E.Turkel, R.F.Warming, H.C. Yee va boshqalarning ishlarida keltirilgan bo’lib, energetik usuldan foydalanib ushbu sxemalarning turg’unligi isbotlangan va amaliy masalalarni yechishda qo’llanilgan.

Differensial tenglamalar va sistemalar qo'yilgan aralash masalalarni sonli yechishda hisoblash usullari yordamida olingan ayirmali sxemalarning turg'unligi isbotlash, approksimatsiya tartibini aniqlash, yaqinlashish tezligi hamda sonli yechim aniqligini baholash R.S.Falk, G.R.Richter, B.A.Szabo, E.L.Wilson, O.C.Zienkievich, K.O.Friedrichs, G.Fix, T.Dupont, B.Swartz, R.Winther, J.Dendy, J.Dondy, L.Whalbin, C.Johnson, V.Thomee, M.Gunzburger, G.Baker, W.Layton, D.F.Christie, T.J.R.Hughes, C.Johnson, S.Nakazawa, U.N.Hvert, W.H.Raymond kabi olimlarning ishlarida keltirilgan. Bugungi kunda mamlakatimizda matematik fizika tenglamalari orqali tavsiflanadigan jarayonlarni matematik modellashtirish va ularni hisoblash usullari bilan yechish muammolari R.D.Aloyev, M.M.Aripov, A.M.Polatov, A.A.Xaldjigitov, Sh.Sh.Zairov va boshqa olimlar tomonidan o'rganilmoqda.

Shu sababli hozirgi kunda matematika o'qituvchisi o'z o'quvchilarini ilgari berilgan faoliyati asosida emas, mavjud sharoitda o'zining ixtiyoriy faoliyatini yaratadigan, zamonaviy fikrlashga, o'qish, o'rganishga, faoliyat olib borishga yo'naltirishi lozim.

Demak, bizning fikrimizcha zamonaviy o'qituvchi "o'zini" fanini o'rganibgina qolmasdan, balki, o'quv – tarbiya jarayonida pedagogik va axborot texnologiyalar asosida dasturlash tillaridan unumli foydalanishni o'rganishi zarur. Shuning bilan birga texnika va texnologiyalarning doimiy yangilanib turishini hisobga oladigan, ta'lim jarayoniga yangilik kiritadigan (novator), tadqiqotchi, ijodiy izlanuvchi qobiliyatiga ega bo'lgan, zamon talabiga tez moslashadigan, bo'lajak matematika fani o'qituvchilarini tayyorlash bizning asosiy vazifamizdir[4].

Tadqiqot metodologiyasi. Hozirgi kunda talaba fanlarni chuqur o'zlashtirishi uchun o'quv rejada berilgan mustaqil ta'limiga yetarlicha katta soat ajratilgan. Talaba auditoriyada egallagan nazariy va amaliy bilimlarini yanada mustahkamlash maqsadida o'z ustida ko'proq ishlashi zarur. Shu sababli talabalar mustaqil bilim olishlari uchun maqola oxirida bir necha adabiyotlar tavsiya etilgan. Elleptik, parabolik, giperbolik tenglamalarning ayirmali sxemalarini qurish va turg'unligini tadqiq qilish [2] batafsil bayon qilingan. Chiziqli tenglamalar sistemasini iteratsion

usullar bilan yechish [5] adabiyotda keltirilgan. [6-10] maqolalarda giperbolik sistemalarni bir va ikki o‘lchovli sohalarda ayirmali sxemalarini qurish va turg‘unliklarini tadqiq qilish, sonli yechish, bir bog‘lamli ikki ulchovli chekli sohalarni approksimatsiya qilish batafsil bayon qilingan. [11] maqolada birinchi tartibli oddiy differensial tenglamalarni sonli yechish usullari keltirilgan.

Talabalarning mustaqil ishlashiga namuna keltiramiz.

1. Masalaning qo‘yilishi. $Q = (0, T) \times \Omega$ sohada

$$\frac{\partial u}{\partial t} = A^2 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) + f(x, y, t), \quad z = (x, y) \in \Omega \quad (1) \quad \text{issiqlik tenglamasining}$$

$u(z, 0) = \varphi(z), \quad z \in \bar{\Omega}, \quad (2) \quad u(z, t) = \psi(z, t), \quad z \in \partial\Omega, 0 \leq t \leq T \quad (3)$ boshlag‘ich va chegaraviy shartlarni qanoatlantiruvchi $u(x, y, t)$ yechimi topilsin. Bu yerda $\Omega = \{z = (x, y) : a < x < b, c < y < d\}$, $\partial\Omega$ - Ω sohaning chegarasi. $A = \text{const} > 0$, $\bar{\Omega} = \Omega \cup \partial\Omega$, $f(z, t), \varphi(z), \psi(z, t)$ - berilgan uzluksiz funksiyalar. (1)-(3) masala korrekt qo‘yilgan deb hisoblaymiz [2].

2. Yechish algoritmi. Dasturga kiritiladigan ma’lumotlar:

1. O‘zgarmaslar: A, T, a, b, c, d ;
2. Funksiyalar: $f(x, y, t), \varphi(x, y), \psi(x, y, t)$;
3. t, x, y bo‘yicha mos ravishda bo‘laklashlar soni N_t, N_x, N_y .

$f(x, y, t), \varphi(x, y), \psi(x, y, t)$ funksiyalar dasturga elementar funksiyalar, xaqiqiy sonlar, arifmetik amallar: + qo‘shish, - ayirish, / - bo‘lish, * - ko‘paytirish yordamida kiritiladi. $p \approx 3.14$ soni pi belgisi bilan kiritiladi. Quyidagi jadvalda elementar funksiyalar va ularni dasturga qanday kiritish ko‘rsatilgan (1-jadvalga qarang).

1-jadval.

Elementar funksiyalarni dasturga kiritilishi jadvali

№	Elementar funksiyalar	Elementar funksiyalarni dasturga kiritish	№	Elementar funksiyalar	Elementar funksiyalarni dasturga kiritish
1	$y= x $	mod (x)	17	$y= \ln x$	ln (x)

2	$y=[x]$	butun (x)	18	$y=\lg x$	$\lg (x)$
3	$y=\{x\}$	kasr (x)	19	$y=\log x$	$\log (x)$
4	$y=x^n, n \in \mathbb{N}$	dar (x:n)	20	$y=\operatorname{sh} x$	$\operatorname{sh} (x)$
5	$y=\sqrt[n]{x}, n \in \mathbb{N}$	ildiz (x:n)	21	$y=\operatorname{th} x$	$\operatorname{th} (x)$
6	$y=\sin x$	$\sin (x)$	22	$y=\operatorname{sch} x$	$\operatorname{sch} (x)$
7	$y=\cos x$	$\cos (x)$	23	$y=\operatorname{ch} x$	$\operatorname{ch} (x)$
8	$y=\operatorname{tg} x$	$\operatorname{tg} (x)$	24	$y=\operatorname{cth} x$	$\operatorname{cth} (x)$
9	$y=\operatorname{ctg} x$	$\operatorname{ctg} (x)$	25	$y=\operatorname{csch} x$	$\operatorname{csch} (x)$
10	$y=\sec x$	$\sec (x)$	26	$y=\operatorname{arsh} x$	$\operatorname{arsh} (x)$
11	$y=\operatorname{cosec} x$	$\operatorname{cosec} (x)$	27	$y=\operatorname{arch} x$	$\operatorname{arch} (x)$
12	$y=\arcsin x$	$\arcsin (x)$	28	$y=\operatorname{arth} x$	$\operatorname{arth} (x)$
13	$y=\arccos x$	$\arccos (x)$	29	$y=\operatorname{arcth} x$	$\operatorname{arcth} (x)$
14	$y=\operatorname{arctg} x$	$\operatorname{arctg} (x)$	30	$y=\operatorname{arcsec} x$	$\operatorname{arcsec} (x)$
15	$y=\operatorname{arcctg} x$	$\operatorname{arcctg} (x)$	31	$y=\operatorname{arccsc} x$	$\operatorname{arccsc} (x)$
16	$y=a^x$	kurs (a:x)	32	$y=e^x$	$e (x)$

Masalan $f(x, y, t) = \sqrt[3]{x^2 + y^2} + e^{5t^3}$ funksiya dasturga quyidagicha kiritiladi
ildiz(dar(X:2)+dar(Y:2):3)+e (5*dar(T:3)).

(1)-(3) masalani to‘r usuli bilan yechamiz. $[0; T]$ kesmani

$t_n = n\tau; n = \overline{0, N_t}; \tau = \frac{T}{N_t}$ nuqtalar bilan N_t ta teng bo‘lakga bo‘lamiz. Xuddi

shunday, $[a; b]$ kesmani $x_i = a + ih_x; i = \overline{0, N_x}; h_x = \frac{b-a}{N_x}$ nuqtalar bilan N_x ta teng

bo‘lakga bo‘lamiz. $[c; d]$ kesmani $y_j = c + jh_y; j = \overline{0, N_y}; h_y = \frac{d-c}{N_y}$ nuqtalar bilan

N_y ta teng bo‘lakga bo‘lamiz. $z_{ij}^n = (x_i, y_j, t_n)$ - to‘r tuguni deyiladi. z_{ij}^n tug‘unda

$u(x, y, t)$ yechimning taqribiy qiymatini u_{ij}^n belgi bilan belgilaymiz, ya’ni

$u(x_i, y_j, t_n) \approx u_{ij}^n$. Xususiyl hosilalarni quyidagicha approksimatsiya qilamiz:

$$\begin{aligned}\frac{\partial u}{\partial t}(x_i, y_j, t_{n+1}) &= \frac{u_{ij}^{n+1} - u_{ij}^n}{\tau} + O(\tau); \\ \frac{\partial^2 u}{\partial x^2}(x_i, y_j, t_{n+1}) &= \frac{u_{i-1j}^{n+1} - 2u_{ij}^{n+1} + u_{i+1j}^{n+1}}{h_x^2} + O(h_x^2); \\ \frac{\partial^2 u}{\partial y^2}(x_i, y_j, t_{n+1}) &= \frac{u_{ij-1}^{n+1} - 2u_{ij}^{n+1} + u_{ij+1}^{n+1}}{h_y^2} + O(h_y^2).\end{aligned}\quad (4)$$

(4) tengliklardan foydalanib (1) tenglama uchun quyidagi oshkormas sxemani hosil qilamiz:

$$\begin{aligned}\frac{u_{ij}^{n+1} - u_{ij}^n}{\tau} &= A^2 \left(\frac{u_{i-1j}^{n+1} - 2u_{ij}^{n+1} + u_{i+1j}^{n+1}}{h_x^2} + \frac{u_{ij-1}^{n+1} - 2u_{ij}^{n+1} + u_{ij+1}^{n+1}}{h_y^2} \right) + f(x_i, y_j, t_{n+1}), \\ n &= \overline{0, N_t - 1}, \quad i = \overline{1, N_x - 1}, \quad j = \overline{1, N_y - 1}.\end{aligned}\quad (5)$$

(5) sxemaning approksimatsiya tartibi $O(\tau + h_x^2 + h_y^2)$. (5) ayirmali tenglamalarni quyidagi ko‘rinishda yozamiz:

$$\begin{aligned}-\frac{A^2 \tau}{h_x^2} u_{i-1j}^{n+1} - \frac{A^2 \tau}{h_y^2} u_{ij-1}^{n+1} + \left[1 + 2A^2 \tau \left(\frac{1}{h_x^2} + \frac{1}{h_y^2} \right) \right] u_{ij}^{n+1} - \\ -\frac{A^2 \tau}{h_x^2} u_{i+1j}^{n+1} - \frac{A^2 \tau}{h_y^2} u_{ij+1}^{n+1} = \tau f(x_i, y_j, t_{n+1}) + u_{ij}^n, \\ n = \overline{0, N_t - 1}, \quad i = \overline{1, N_x - 1}, \quad j = \overline{1, N_y - 1}.\end{aligned}\quad (6)$$

Boshlang‘ich va chegaraviy shartlarni quyidagicha approksimatsiya qilamiz:

$$\begin{aligned}u_{ij}^0 &= \varphi(x_i, y_j), \quad z_{ij} = (x_i, y_j) \in \overline{\Omega_h}, \\ u_{ij}^{n+1} &= \varphi(x_i, y_j, t_{n+1}), \quad z_{ij} = (x_i, y_j) \in \partial\Omega_h, \\ 0 &< t_{n+1} < \tau N_t, \quad n = \overline{0, N_t - 1}.\end{aligned}\quad (7)$$

Bu yerda $\Omega_h = \{z_{ij} = (x_i, y_j) : a < x_i < b, c < y_j < d\}$.

(6)-(7) masala turg‘un ([2], 181- bet, 2-teoremaga qarang). nisbatan hosil bo‘lgan (6) chiziqli tenglamalar sistemasi (7) bilan birgalikda yopiq sistema. (6) chiziqli tenglamalar sistemasida diogonal ustunlik sharti bajariladi[5]. Shu sababli (6) chiziqli tenglamalar sistemasini Zeydel usuli bilan yechamiz[5].

Shu algoritm asosida Delphi-7 dasturlash muhitida to‘g‘ri to‘rtburchakli sohada (1)-(3) masalani sonli yechadigan va yechim grafigini chizadigan dastur yaratilgan. Yaratilgan dasturning ishlashi hisoblash tajribalarida tekshirilgan.

Tahlil va natija.

3. Sonli hisoblar. Masala. $Q = \{0 < x < 5, 0 < y < 5, 0 < t < 5\}$ sohada

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} - 3 \quad (8)$$

Issiqlik tenglamasining

$$u(x, y, 0) = x^2 + y^2 \quad (9)$$

boshlang‘ich shartni va

$$\begin{aligned} u(0, y, t) &= y^2 + t, \quad 0 \leq y \leq 5, 0 \leq t \leq 5; \\ u(5, y, t) &= y^2 + t + 25, \quad 0 \leq y \leq 5, 0 \leq t \leq 5; \\ u(x, 0, t) &= x^2 + t, \quad 0 \leq x \leq 5, 0 \leq t \leq 5; \\ u(x, 5, t) &= x^2 + t + 25, \quad 0 \leq x \leq 5, 0 \leq t \leq 5. \end{aligned} \quad (10)$$

chegaraviy shartlarni qanoatlantiruvchi $u(x, y, t)$ yechimi topilsin. (8)-(10)

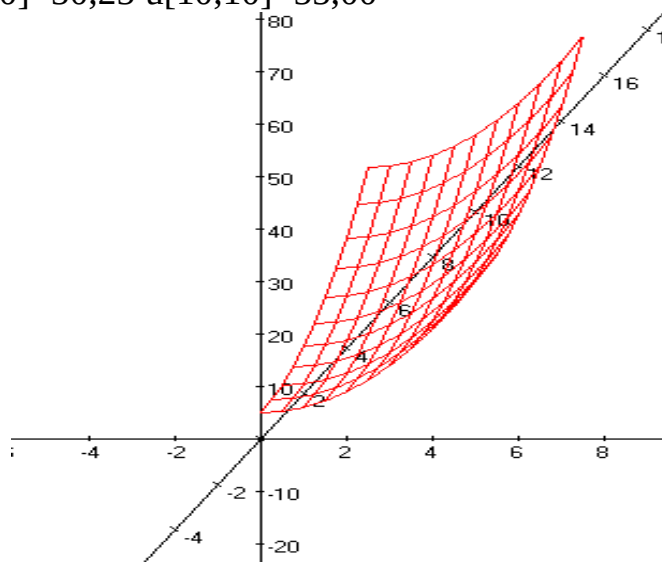
masalaning aniq yechimi $u(x, y, t) = x^2 + y^2 + t$.

Yechish. Quyida $T = 5$ da, $N_x = 10, N_y = 10, N_t = 20$ bo‘lganda (8)-(10)

masalaning tugunlarda taqribiy yechimi keltirilgan.

$u[0,0]=5,00$ $u[1,0]=5,25$ $u[2,0]=6,00$ $u[3,0]=7,25$ $u[4,0]=9,00$ $u[5,0]=11,25$
 $u[6,0]=14,00$ $u[7,0]=17,25$ $u[8,0]=21,00$ $u[9,0]=25,25$ $u[10,0]=30,00$ $u[0,1]=5,25$
 $u[1,1]=5,50$ $u[2,1]=6,25$ $u[3,1]=7,50$ $u[4,1]=9,25$ $u[5,1]=11,50$ $u[6,1]=14,25$
 $u[7,1]=17,50$ $u[8,1]=21,25$ $u[9,1]=25,50$ $u[10,1]=30,25$ $u[0,2]=6,00$ $u[1,2]=6,25$
 $u[2,2]=7,00$ $u[3,2]=8,25$ $u[4,2]=10,00$ $u[5,2]=12,25$ $u[6,2]=15,00$ $u[7,2]=18,25$
 $u[8,2]=22,00$ $u[9,2]=26,25$ $u[10,2]=31,00$ $u[0,3]=7,25$ $u[1,3]=7,50$ $u[2,3]=8,25$
 $u[3,3]=9,50$ $u[4,3]=11,25$ $u[5,3]=13,50$ $u[6,3]=16,25$ $u[7,3]=19,50$ $u[8,3]=23,25$
 $u[9,3]=27,50$ $u[10,3]=32,25$ $u[0,4]=9,00$ $u[1,4]=9,25$ $u[2,4]=10,00$ $u[3,4]=11,25$
 $u[4,4]=13,00$ $u[5,4]=15,25$ $u[6,4]=18,00$ $u[7,4]=21,25$ $u[8,4]=25,00$ $u[9,4]=29,25$
 $u[10,4]=34,00$ $u[0,5]=11,25$ $u[1,5]=11,50$ $u[2,5]=12,25$ $u[3,5]=13,50$ $u[4,5]=15,25$
 $u[5,5]=17,50$ $u[6,5]=20,25$ $u[7,5]=23,50$ $u[8,5]=27,25$ $u[9,5]=31,50$ $u[10,5]=36,25$
 $u[0,6]=14,00$ $u[1,6]=14,25$ $u[2,6]=15,00$ $u[3,6]=16,25$ $u[4,6]=18,00$ $u[5,6]=20,25$
 $u[6,6]=23,00$ $u[7,6]=26,25$ $u[8,6]=30,00$ $u[9,6]=34,25$ $u[10,6]=39,00$ $u[0,7]=17,25$
 $u[1,7]=17,50$ $u[2,7]=18,25$ $u[3,7]=19,50$ $u[4,7]=21,25$ $u[5,7]=23,50$ $u[6,7]=26,25$

$u[7,7]=29,50$ $u[8,7]=33,25$ $u[9,7]=37,50$ $u[10,7]=42,25$ $u[0,8]=21,00$ $u[1,8]=21,25$
 $u[2,8]=22,00$ $u[3,8]=23,25$ $u[4,8]=25,00$ $u[5,8]=27,25$ $u[6,8]=30,00$ $u[7,8]=33,25$
 $u[8,8]=37,00$ $u[9,8]=41,25$ $u[10,8]=46,00$ $u[0,9]=25,25$ $u[1,9]=25,50$ $u[2,9]=26,25$
 $u[3,9]=27,50$ $u[4,9]=29,25$ $u[5,9]=31,50$ $u[6,9]=34,25$ $u[7,9]=37,50$ $u[8,9]=41,25$
 $u[9,9]=45,50$ $u[10,9]=50,25$ $u[0,10]=30,00$ $u[1,10]=30,25$ $u[2,10]=31,00$
 $u[3,10]=32,25$ $u[4,10]=34,00$ $u[5,10]=36,25$ $u[6,10]=39,00$ $u[7,10]=42,25$
 $u[8,10]=46,00$ $u[9,10]=50,25$ $u[10,10]=55,00$



$u(x, y, t)$ yechim grafigi.

Xulosa va takliflar. Xulosa qilib aytganda, oliy ta’lim muassasalari matematika yo‘nalishi talabalari uchun o‘qituvchining kreativ yondashuv asosida “Differensial tenglamalar” bilan “Dasturlash” fanlararo integratsiyasini ko‘rsatish orqali talabalarning fanlar nisbatan qiziqishi ortiradi. Fizika, ximiya, biologiya, iqtisod va boshqa sohalarda analitik usullar bilan yechib bo‘lmaydigan differensial tenglamalar va sistemalar keladigan masalalar juda ko‘p. Bu masalalarni sonli hisoblash usullari bilan yechish mumkin. Shu sababli talabalarning malakali kadrlar bo‘lib yetishishi uchun axborot texnologiyalarining imkoniyatlarini keng ochib berishimiz lozim. Ushbu maqola va quyida keltirilgan adabiyotlar talabalarga axborot texnologiyalari imkoniyatlaridan foydalanib matematik masalalarni yechish mumkinligini ko‘rsatib beradi.

Mustaqil yechish uchun misollar.

- 1) $Q = \{0 < x < 5, 0 < y < 5, 0 < t < 2\}$ sohada

$$\frac{\partial u}{\partial t} = 2 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) - 8 + xy$$

issiqlik tenglamasining

$$u(x, y, 0) = x^2 + y^2$$

boshlang‘ich shartni va

$$u(0, y, t) = y^2, \quad 0 \leq y \leq 5, \quad 0 \leq t \leq 2;$$

$$u(5, y, t) = 5yt + y^2 + 25, \quad 0 \leq y \leq 5, \quad 0 \leq t \leq 2;$$

$$u(x, 0, t) = x^2, \quad 0 \leq x \leq 5, \quad 0 \leq t \leq 2;$$

$$u(x, 5, t) = x^2 + 5xt + 25, \quad 0 \leq x \leq 5, \quad 0 \leq t \leq 2.$$

chegaraviy shartlarni qanoatlantiruvchi $u(x, y, t)$ yechimi topilsin.

2) $Q = \{0 < x < 2, 0 < y < 5, 0 < t < 2\}$ sohada

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + x^2 y - 2yt$$

issiqlik tenglamasining

$$u(x, y, 0) = 0$$

boshlang‘ich shartni va

$$u(0, y, t) = 0, \quad 0 \leq y \leq 5, \quad 0 \leq t \leq 2;$$

$$u(2, y, t) = 4yt, \quad 0 \leq y \leq 5, \quad 0 \leq t \leq 2;$$

$$u(x, 0, t) = 0, \quad 0 \leq x \leq 2, \quad 0 \leq t \leq 2;$$

$$u(x, 5, t) = 5x^2 t, \quad 0 \leq x \leq 2, \quad 0 \leq t \leq 2.$$

chegaraviy shartlarni qanoatlantiruvchi $u(x, y, t)$ yechimi topilsin.

3) $Q = \{0 < x < \pi/2, 0 < y < \pi, 0 < t < 5\}$ sohada

$$\frac{\partial u}{\partial t} = 3 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) + (1 - 6t) \sin x \cos y$$

issiqlik tenglamasining

$$u(x, y, 0) = 0$$

boshlang‘ich shartni va

$$u(0, y, t) = 0, \quad 0 \leq y \leq \pi, \quad 0 \leq t \leq 5;$$

$$u(\pi/2, y, t) = t \cos y, \quad 0 \leq y \leq \pi, \quad 0 \leq t \leq 5;$$

$$u(x, 0, t) = t \sin x, \quad 0 \leq x \leq \pi/2, \quad 0 \leq t \leq 5;$$

$$u(x, \pi, t) = -t \sin x, \quad 0 \leq x \leq \pi/2, \quad 0 \leq t \leq 5.$$

chegaraviy shartlarni qanoatlantiruvchi $u(x, y, t)$ yechimi topilsin.

4) $Q = \{0 < x < 5, 0 < y < 5, 0 < t < 3\}$ sohada

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{(x^2 + y^2)t}{\sqrt{(1+t^2)^3}} + \frac{4}{\sqrt{1+t^2}}$$

issiqlik tenglamasining

$$u(x, y, 0) = -(x^2 + y^2)$$

boshlang‘ich shartni va

$$u(0, y, t) = -\frac{y^2}{\sqrt{1+t^2}}, \quad 0 \leq y \leq 5, \quad 0 \leq t \leq 3;$$

$$u(5, y, t) = -\frac{y^2 + 25}{\sqrt{1+t^2}}, \quad 0 \leq y \leq 5, \quad 0 \leq t \leq 3;$$

$$u(x, 0, t) = -\frac{x^2}{\sqrt{1+t^2}}, \quad 0 \leq x \leq 5, \quad 0 \leq t \leq 3;$$

$$u(x, 5, t) = -\frac{x^2 + 25}{\sqrt{1+t^2}}, \quad 0 \leq x \leq 5, \quad 0 \leq t \leq 3.$$

chegaraviy shartlarni qanoatlantiruvchi $u(x, y, t)$ yechimi topilsin.

5) $Q = \{0 < x < 2, 0 < y < 2, 0 < t < 4\}$ sohada

$$\frac{\partial u}{\partial t} = 4 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) + \frac{x^2 + y^2}{2\sqrt{t+1}} - 16\sqrt{t+1}$$

issiqlik tenglamasining

$$u(x, y, 0) = x^2 + y^2$$

boshlang‘ich shartni va

$$u(0, y, t) = y^2 \sqrt{t+1}, \quad 0 \leq y \leq 2, \quad 0 \leq t \leq 4;$$

$$u(2, y, t) = (4 + y^2) \sqrt{t+1}, \quad 0 \leq y \leq 2, \quad 0 \leq t \leq 4;$$

$$u(x, 0, t) = x^2 \sqrt{t+1}, \quad 0 \leq x \leq 2, \quad 0 \leq t \leq 4;$$

$$u(x, 2, t) = (4 + x^2) \sqrt{t+1}, \quad 0 \leq x \leq 2, \quad 0 \leq t \leq 4.$$

chegaraviy shartlarni qanoatlantiruvchi $u(x, y, t)$ yechimi topilsin.

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