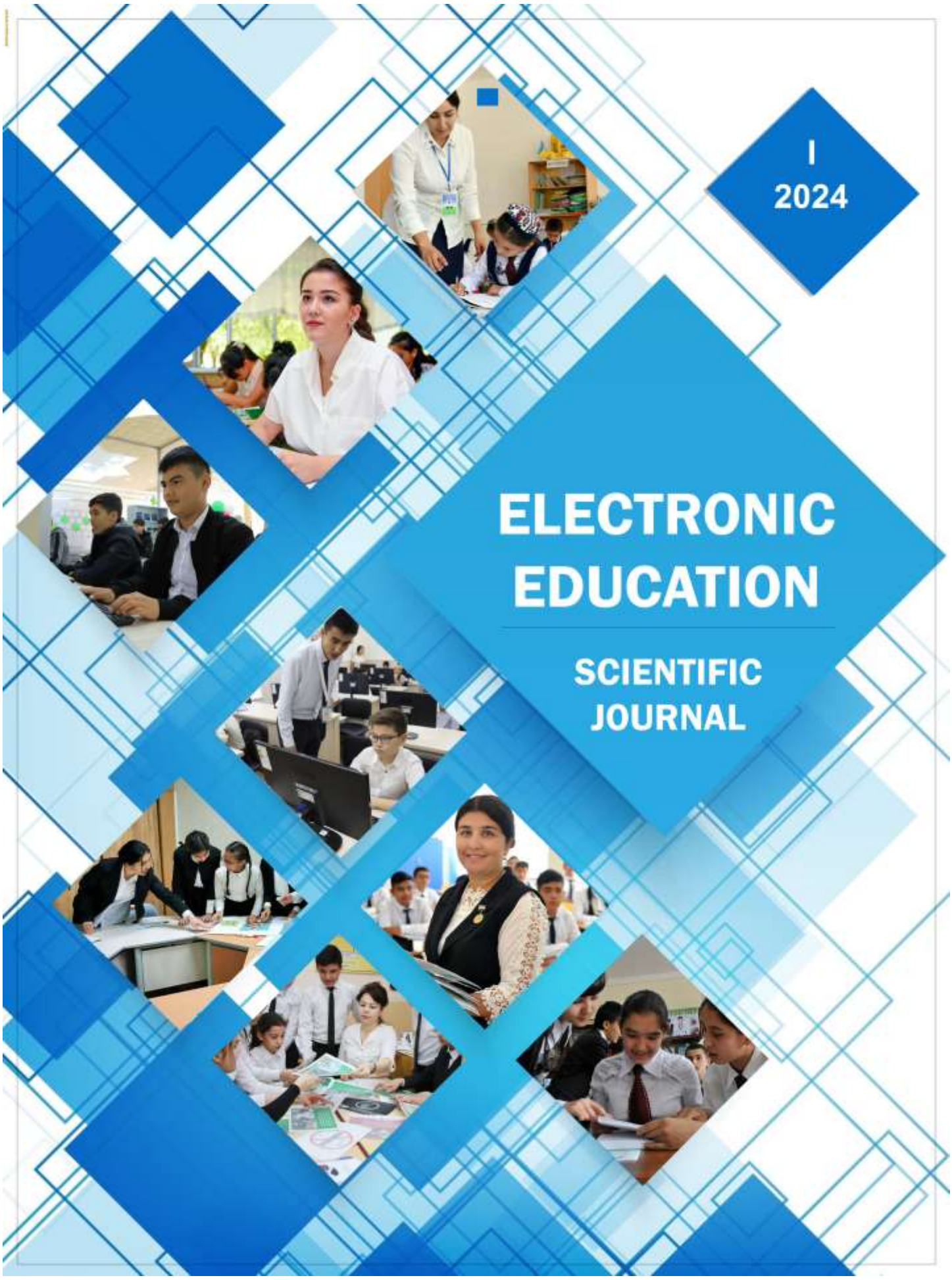

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TO‘G‘RI TO‘RTBURCHAKLI SOHADA ISSIQLIK TENGLAMASINI TO‘R METODI BILAN SONLI YECHISH

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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

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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

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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 sohalarning qator muammolarini tadqiq etish differensial tenglamalar va sistemalarga 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.Fridrixs, 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 sistemalarga qo‘yilgan aralash masalalarni ayirmali sxemalar yoki chekli elementlar usullari yordamida sonli yechilgan.

Differensial tenglamalar va sistemalarga 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 sistemalarga 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 ilgaridan berilgan faoliyati asosida emas, mavjud sharoitda o‘zininig 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 kirita oladigan (novator), tadqiqotchi, ijodiy izlanuvchi qobiliyatiga ega bo‘lgan, zamon talabiga tez moslasha oladigan, 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‘unliglariini 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 $\frac{\partial u}{\partial t}=A^2(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2})+f(x,y,t),\ \ z=(x,y)\in\Omega$ (1) issiqlik tenglamasining $u(z,0)=\varphi(z),\ z\in\overline{\Omega},$ (2) $u(z,t)=\psi(z,t),\ z\in\partial\Omega, 0\le t\le T$ (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. $A=const>0$, $\overline{\Omega}=\Omega\cup\partial\Omega$, $f(z,t),\varphi(z),\psi(z,t)$ -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≈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	$y=x^n$, nЄN	dar (x:n)	20	y= sh x	sh (x)
5	$y=\sqrt[n]{x}$, nЄN	ildiz (x:n)	21	y= th x	th (x)
6	y= sinx	sin (x)	22	y= sch x	sch (x)
7	y= cos x	cos (x)	23	y= ch x	ch (x)
8	y=tg x	tg (x)	24	y= cth x	cth (x)
9	y=ctg x	ctg (x)	25	y= csch x	csch (x)
10	y= sec x	sec (x)	26	y= arsh x	arsh (x)
11	y=cosec x	cosec (x)	27	y= arch x	arch (x)
12	y= arcsin x	arcsin (x)	28	y= arth x	arth (x)
13	y= arccos x	arccos (x)	29	y= arcth x	arcth (x)
14	y= arctg x	arctg (x)	30	y= arcsec x	arcsec (x)
15	y= arcctg x	arcctg (x)	31	y= arccsc x	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 $t_n=n\tau;\ n=\overline{0,N_t};\ \tau=\dfrac{T}{N_t}$ nuqtalar bilan N_t ta teng bo‘lakga bo‘lamiz. Xuddi shunday, $[a;b]$ kesmani $x_i=a+ih_x;\ i=\overline{0,N_x};\ h_x=\dfrac{b-a}{N_x}$ nuqtalar bilan N_x ta teng bo‘lakga bo‘lamiz. $[c;d]$ kesmani $y_j=c+jh_y;\ j=\overline{0,N_y};\ h_y=\dfrac{d-c}{N_y}$ 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 $u(x_i,y_j,t_n)\approx u_{ij}^n$. Xususiy hosilalarni quyidagicha approksimatsiya qilamiz:

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

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

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

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

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

Boshlang‘ich va chegaraviy shartlarni quyidagicha approksimatsiya qilamiz:

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

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 dioganal 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

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

Issiqlik tenglamasining

$$u(x,y,0)=x^2+y^2 \tag{9}$$

boshlang‘ich shartni va

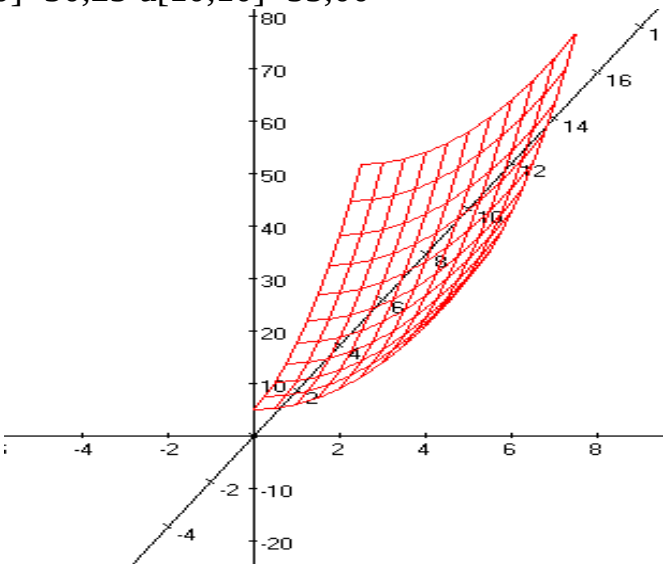
$$\begin{aligned} &u(0,y,t)=y^2+t,\ 0\le y\le 5,\ 0\le t\le 5;\\ &u(5,y,t)=y^2+t+25,\ 0\le y\le 5,\ 0\le t\le 5;\\ &u(x,0,t)=x^2+t,\ 0\le x\le 5,\ 0\le t\le 5;\\ &u(x,5,t)=x^2+t+25,\ 0\le x\le 5,\ 0\le t\le 5. \end{aligned} \tag{10}$$

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 $T=5$ да, $N_x=10, N_y=10, N_t=20$ 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 sistemalarga 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

$$u(0,y,t)=y^2,\ 0\le y\le 5,\ 0\le t\le 2;$$
$$u(5,y,t)=5yt+y^2+25,\ 0\le y\le 5,\ 0\le t\le 2;$$
$$u(x,0,t)=x^2,\ 0\le x\le 5,\ 0\le t\le 2;$$
$$u(x,5,t)=x^2+5xt+25,\ 0\le x\le 5,\ 0\le t\le 2.$$

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

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

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

issiqlik tenglamasining

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

boshlang‘ich shartni va

$$u(0,y,t)=0,\ 0\le y\le 5,\ 0\le t\le 2;$$
$$u(2,y,t)=4yt,\ 0\le y\le 5,\ 0\le t\le 2;$$
$$u(x,0,t)=0,\ 0\le x\le 2,\ 0\le t\le 2;$$
$$u(x,5,t)=5x^2t,\ 0\le x\le 2,\ 0\le t\le 2.$$

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

$$u(0,y,t)=0,\ 0\le y\le \pi,\ 0\le t\le 5;$$
$$u(\pi/2,y,t)=t\cos y,\ 0\le y\le \pi,\ 0\le t\le 5;$$
$$u(x,0,t)=t\sin x,\ 0\le x\le \pi/2,\ 0\le t\le 5;$$
$$u(x,\pi,t)=-t\sin x,\ 0\le x\le \pi/2,\ 0\le t\le 5.$$

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

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

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

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

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

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

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

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

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

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

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

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