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08.00.03 Sanoat iqtisodiyoti
08.00.04 Qishloq xo'jaligi iqtisodiyoti
08.00.05 Xizmat ko'rsatish tarmoqlari iqtisodiyoti
08.00.06 Ekonometrika va statistika
08.00.07 Moliya, pul muomalasi va kredit
08.00.08 Buxgalteriya hisobi, iqtisodiy tahlil va audit
08.00.09 Jahon iqtisodiyoti
08.00.10 Demografiya. Mehnat iqtisodiyoti
08.00.11 Marketing
08.00.12 Mintaqaviy iqtisodiyot
08.00.13 Menejment
08.00.14 Iqtisodiyotda axborot tizimlari va texnologiyalari
08.00.15 Tadbirkorlik va kichik biznes iqtisodiyoti
08.00.16 Raqamli iqtisodiyot va xalqaro raqamli integratsiya
08.00.17 Turizm va mehmonxona faoliyati

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MUNDARIJA

“Zavur kollektor suvlarining kimyoviy tarkibi tahlili va ularni tozalash zarurati (Qoraqalpog‘iston Respublikasi misolida)”.....	20
Kungiratbay Sharipov, Ma‘ruf Nurmanov	
Forming demand and stimulating sales in Uzbekistan.....	26
Musayeva Shoirazimovna	
Членство в ВТО как драйвер развития: взгляд Узбекистана через призму опыта Вьетнама и Казахстана.....	30
Ж.Я.Нуриллаев	
Mamlakatimizda tizimli ahamiyatga molik banklarni aniqlash tartibi va ularning bank tizimi moliyaviy barqarorligiga ta'siri tahlili.....	37
Xolmamatov Farhodjon Kubaevich	
O'zbekiston respublikasida aholi bandligini ta'minlashdagi dolzarb masalalar	44
Ibragimov Elmurod Gulboynor o'g'li	
O'zbekiston respublikasida elektr energiyasi ta'minoti hajmini yalpi ichki mahsulot hajmiga ta'sirini ekonometrik tahlil qilish	48
Fayziyev Rabim Alikulovich	
Raqamli iqtisodiyot sharoitida tijorat banklarining xizmat turlarini takomillashtirish amaliyoti	60
Umurzoqova Adiba Ochilovna	
Qishloq xo'jaligi kooperativi boshqaruv tizimida buxgalteriya hisobini tashkil qilishning o'ziga xos xususiyatlari	67
Abduraxmanov Ramazon Abdullayevich	
O'zbekistonda qishloq xo'jaligi mahsulotlari umumiy hajmini prognozlashda ekonometrik modellar (yillik)	72
Qodirov Farxod Amirovich, Bo'riyeva Qundiz Muratbaevna	
Oziq-ovqat mahsulotlari xavfsizligi tizimini takomillashtirishning nazariy va amaliy jihatlari.....	77
Mahamatova Maftuna	
Xufiyona va yashirin iqtisodiyotning amaliy tahlili o'zbekiston miqyosida.....	83
Koshanov Abdimurat Azat uli	
Soliq tizimini barqarorligini belgilovchi omillar tahlili.....	87
Nurillayev Jasurbek Davronbekovich	
Mahalliy budjetlar daromad manbalarini mustahkamlash omillari.....	92
Soatova Nodira Boboxanovna	
Bank infratuzilmasining raqamli transformatsiyasi va resurslar bazasi shakllanishi: nazariy asoslar va texnologik yondashuvlar.....	97
Raxmatov Azizjon Jaloliddinovich, Jumayev Muzaffar Mahmud o'g'li	
Ichki auditning transformatsion potentsiali: tahliliy amallarni takomillashtirish orqali samaradorlikni oshirish.....	102
Misirov Akbarali Pardaboyevich, Ismoilov Asadbek Abdusamat o'g'li	
Xorijiy mamlakatlarda yashil moliyalashtirishni rivojlantirish yo'llari.....	110
Qorriyeva Shahnoza Safarbayevna	
Yashil moliya – iqtisodiy rivojlanish mexanizmi sifatida	117
Nodir Xidirov G'iyosaliyevich	
Xo'jalik yurituvchi subyektlarning likvidliligi va moliyaviy barqarorligini ta'minlashning xorij tajribasi va uning amaliy ahamiyati	122
Bauyetdinov M.J.	
Теоретические подходы к определениям агрессии социально - экономической и политической стабильности государства как фактор повышения рекреационных потребностей	128
Алимова Райхона Баходировна	
Innovatsion ta'lim texnologiyalari asosida talabalarning metodik tayyorgarligini shakllantirish.....	139
Komilov Umidjon Normurod o'g'li, Tulyaganova Gulnoza Olimjon qizi	



Kichik biznes subyektlarini moliyalashtirish manbalari	143
Nematulloyev Suxrob Sobirovich	
Bir qatlamli elastik asosda joylashgan to'sinning seysmik kuchlar ta'siridagi tebranishining V.Z. Vlasov usuli asosida analitik tadqiqi	148
Kamola Xaydarova	
"Sibir daryolarining burilishi" loyihasining tarixiy va retrospektiv tahlili	153
Mahmudov Nosir Mahmudovich	
Sarguzasht turizmini rivojlanishi va sarguzasht turlarda turistlarning xavfsizligini ta'minlashda instruktor-gidlarning roli	159
Tilovmurodov Dostonbek Furqat o'g'li	
Scientific-theoretical foundations of the use of ict in ensuring management efficiency and security in enterprises	165
Khalilov Bekzod Akhmatovich	
Tijorat banklarida kredit riskini boshqarish mexanizmlarini takomillashtirish yo'nalishlari.....	171
Mirtursunova Dinara Anvarovna	
O'zbekiston respublikasi tijorat banklarida masofaviy bank xizmatlarini joriy etishni takomillashtirish yo'llari.....	175
Tangriyev Izzat Raxmatullayevich	
Qashqadaryo viloyatida eko va etno turizmni rivojlantirishning istiqbollari va iqtisodiy samaradorligi.....	181
Erkayeva Barno, Xushvaqto'v Ramziddin	
O'zbekiston bank tizimida raqamli valyutalar va yashil investitsiyalar integratsiyasini takomillashtirish	186
Nodirov Azizxon Asrorovich	
Global energiya noaniqligining o'zgaruvchanligi ekonomertik modellari	192
Bexzod Qo'ziboev	
Экоцифра: цифровизация МСП для зеленого устойчивого роста	197
С.С. Убаева	
Qishloq xo'jaligini barqaror rivojlantirish va ekologik toza hududni yo'lga qo'yishning ahamiyati.....	201
Ergashov Ulug'bek Zoxidjonovich	
Statistika fanining shakllanish bosqichlari va rivojlanish tendensiyalari.....	206
Nabixodjaev Abbas Abdupattahovich, Umarova Mukaddas Abbasovna	
Hududlarning atmosferaga chiqaradigan zararli chiqindilar miqdorini sanoat mahsulotiga nisbati bo'yicha tahlili.....	210
Baqoyev Husan Nuriddinovich	
Qayta tiklanadigan vodorod narxlari strategiyasini o'rganish: xarajat noaniqliklarini bartaraf etish	216
Nuraliyeva Komila Sanakulovna	
Qishloq xo'jaligini "yashil" iqtisodiyot asosida rivojlantirishga o'tishning zarurligi va mohiyati	221
Yoldoshev Mutalib Ibrohimovich	
Mamlakat iqtisodiyotini rivojlantirishda "yashil investitsiyalar" dan foydalanishning xorij tajribalari	225
Ruzibayeva Nargiza Xakimovna, Rustamova Nasiba Arslanovna	
Ijtimoiy iqtisodiy ehtiyojlar va ularning iqtisodiy rivojlanishdagi o'rni.....	230
Raxmonova Feruza Musaqulovna	
Oliy ta'lim xizmatlarini ijtimoiy-iqtisodiy taraqqiyotda tutgan o'rni.....	234
Mirzaxajeva Shaxzoda Shuxratovna	
Tijorat banklari muammoli kreditlarining likvidlikka ta'siri.....	240
Karshiyev Adham Anvarovich	
Kichik firmalarning raqobatbardoshligini oshirishning nazariy metodologik jihatlar.....	245
Ruzmetov Davron Ibrogimovich, Aliyev Maqsudbek Erkinovich	
Xo'jalik yurituvchi subyektlarning moliyaviy resurslaridan samarali foydalanish imkoniyatlari.....	251
Talapova Nargiza Baxriddinovna	



“Deviant xulq-atvorli o’smirlarning ijtimoiy moslashuvining psixologik xususiyatlari”	255
Saidbekova Feruza Anvarbek qizi	
Aholi daromadlarini diversifikatsiya qilishda davlat siyosatining roli va imkoniyatlari	258
Nutfullayev Shohrux Mexli o’g’li, Qurbanov Ulug’bek Erkinovich	
Анализ показателей развития зелёной химии по всему миру и в узбекистане за последние десять лет	262
Фозилова Фирангиза Комиловна	
Tijorat banklarining o’zbekiston respublikasi iqtisodiyotiga ta’siri	270
Masharipov Rasulbek Jo’rabekovich	
Biznes birlashuvda buxgalteriya hisobi va auditni takomillashtirish yo’nalishlari	273
Hamroyeva Zuhra Amiral qizi, Xayitboyeva Laylo Oybekovna, Mirzarayimov Sardorbek Ravshanovich	
O’zbekiston respublikasida pul-kredit siyosatining maqsadi	277
Adilov Zuxriddin Marip o’g’li	
Qishloq xo’jaligi mahsulotlarining ishlab chiqarish va bozorlararo aloqalarining statistik o’zgarish tendensiyalari	281
Zakirova Umida Maxamadaminovna	
Iqtisodiy bilimlarni shakllanishi va rivojlanishi	286
Po’latov Abdulloh Xolxo’jayevich	
Теоретические основы эффективного управления финансовыми ресурсами предприятий с государственной долей (на примере узбекистана)	291
Ахмедов Дилшод Турсункулович	
Robototexnika asoslari va maktab ta’limida qo’llanilishi	298
Tuxliyev Muslimbek Sherzod o’g’li	
Sun’iy intellektlar yordamida o’quvchilarni hayotiy faoliyat ko’nikmasini shakllantirishi	303
Mirxasilova Zulfiya Kochkarovna, Abdurahmanova Ozoda Djo’rayevna, Kurbanov Azimjon Jo’raboy o’g’li	
Levi tengsizligi uchun A.N. Kolmogorov teoremlari	316
Saypiddinov Shukrullo Sadrdinovich, Baxramov Rustamjon Qambarali o’g’li	
Rivojlanayotgan mamlakatlar bank tizimida raqamli moliyaviy texnologiyalarni joriy etish afzalliklari	320
Xodjimamedov Akmal Ashurovich, Umedov Abdullo Umedovich	
O’zbekiston respublikasining mdh mamlakatlari bilan tashqi savdo faoliyati tahlili: o’zgarish tendensiyalari va istiqbollari	326
Ilyosov Asrorjon Axrorjon o’g’li, Abdullaev Alisher Maxmudovich, Tuxtasinova Muxayyo Mirzasultonovna	
Elektron tijoratni rivojlantirishning xorij tajribasi	330
Madieva Zuxra Iskandarbekovna	
Inson resurslarini o’rganishning asosiy yondashuvlari: mohiyat-ta’rifiy tahlil	336
Bakirov Qobiljon Mamatyusupovich	
Bandlikni ta’minlashda davlat tomonidan institutsional muhit yaratishning roli	340
Dilorom Tojiboyeva, Umida Ravshanovna Anvarova	
Mamlakatimizda islom moliyasini rivojlantirish maqsad va choralari	346
Xoliyorov Xomid Boynazarovich	
Разработка экспертной системы для оценки финансового состояния предприятия	352
Tajibayeva Kizlargul Ajiniyazovna	
Farg’ona vodiysi viloyatlarida kichik biznes ko’rsatkichlarining o’zgarishi: panel regressiya tahlili	362
Tojiyeva Muhabbatxon Mansurjon qizi	
O’zbekiston Respublikasida makroiqtisodiy ko’rsatkichlarni hisoblashdagi asosiy muammolar va ularning yechimlari	368
Farmonov Ilhomjon Iqboljon o’g’li	
Xorijiy tajriba asosida korxonalar innovatsion faolligini boshqarishni takomillashtirish	374
Hakimova Nozimaxon Sobirjon qizi	
Mahalliy davlat hokimiyati organlarida milliy kadrlar zaxirasini shakllantirish	380
G’aniev Elyor Sobirjonovich	
O’zbekistonda sirkulyar iqtisodiyotga o’tishning ahamiyati	386
Mirzayev Muzaffar Maxmudovich	



The role of international investments in greening and ecological rehabilitation of the aral sea region	392
Ospanova Feruza Bazarbaevna	
“Зеленое направление” совершенствования бухгалтерского учета	397
Ибрагимов Гайратжон Артикович	
Xarajatlarni kelib chiqish joylari va javobgarlik markazlari bo'yicha hisobga olishni takomillashtirish	403
Xamidova S.Ya.	
Mintaqalarni iqtisodiy rivojlantirishning metodologik asoslari va ularni takomillashtirish.....	409
Toshaliyeva Saodat Toxirovna	
O'zbekistonda kichik turar joy biznesini rivojlantirishda xorijiy tajribalar	414
Yo'ldashev Bekzodjon Sherzodjon o'g'li	
Tijorat banklarida davlat maqsadli dasturlarini moliyalashtirish yuzasidan ilmiy-nazariy qarashlar.....	419
Shodiyev Shuhrat Sunnat o'g'li	
Qandolat mahsulotlari bozorida marketing strategiyalaridan foydalanishning xorijiy mamlakatlar tajribasi.....	426
Azlarova Munira Muxammad-Amin qizi	
Risk management in commercial banks, methodological approaches and practical implementation	433
Baymuratova Zina Aqilbekovna, Jarilkapova Naubaxar Paraxat qizi	
The impact of competition on economic growth: evidence from uzbekistan's automotive industry.....	439
Saydaliyeva Dilrabo Baxriddin qizi	
Raqamli texnologiyalarning oliy talim xizmatlarini rivojlantirishdagi o'rni.....	444
Mirzaxadjayeva Shahzoda Shuxratovna	
Развитие производства сельскохозяйственной продукции путем развития цифровых технологий.....	450
Юсупов Мухиддин Соатович	
Tijorat banklarida loyihaviy moliyalashtirish risklarini boshqarish amaliyotini takomillashtirish	457
Berdiyev Akram O'ktamovich	
Iqtisodiy tarmoqlarni soliqqa tortish orqali investitsiya loyihalarini rivojlantirish.....	463
Sharipov Eldor Salohiddin o'g'li	
Iqtisodiyotda investitsiya va kredit salohiyatini bank faoliyatiga ta'siri.....	468
Ergashova Nilufar Sobirovna	
Qurilish materiallari sanoati korxonalarining raqobatbardoshlik salohiyatini boshqarishni takomillashtirish	473
Tashmukhamedova Karima Samatovna	
Ziyorat turizmini rivojlantirishning asosiy yo'nalishlari va istiqbollari.....	479
Kurbanova Mohinur Xabib qizi	
Xalqaro sayohat lug'ati va uning shakllanishi.....	487
Abduaxadova Zilola Djamoliddinovna	
Moliyaviy hisobotning xalqaro standartlari va uni o'zbekiston respublikasi hisob tizimini rivojlantirishdagi o'rni va ahamiyati.....	492
Quvvatov G'olibjon Baxtiyor o'g'li	
Kooperatsiyalarning tutgan o'rni va ahamiyati.....	501
Mirzayev Musurmon Umidullayevich, Ziyadullayev Ilhom Narkobilovich	
Использование методов математического моделирования при внедрении коммерческих автоматических систем	505
Курбанова Рахима, Ахмедов Мехрохжон	
Tijorat banklari kapitalidagi davlat ulushini kamaytirish yo'llari.....	511
Vasiyev Alisher Samiyevich	
Механизмы трансформации неформального сектора в официальную экономику на основе финансовых инструментов.....	515
Кошанов Абдимурат Азат ули, Муртазаев Шахрух Коньскайлиевич	



The impact of tourism on the economy of Uzbekistan	519
Xaydarova Marjona, Muxamedboyeva Muxlisa, Umarov Kamron, Usmanova Aziza	
Mintaqada gastroturizm rivojlanishining iqtisodiy asoslari va zamonaviy tendensiyalari	525
Masharipova Manzura Alimbayevna	
Tikuv-trikotaj korxonalari brend jozibadorligini oshirishning ilmiy-nazariy jihatlarini	535
O'rinov Akmaljon Axmadjonovich	
Bank tizimida hisobotlarni avtomatlashtirish texnologiyalari	542
Sodiqov Sanjar Saydullo o'g'li	
Engineering programs in Uzbekistan on the verge of fifth industrial revolution	547
Khasan Khankeldiyev	
Aksiyadorlik jamiyatlarining boshqaruvini yaxshilashda korporativ madaniyatning ahamiyati	551
Akramova Nazokat Israilovna	
Tadbirkorlik faoliyatining iqtisodiy taraqqiyotdagi o'rni	562
Amonov Mehridin Oromiddinovich	
O'zbekiston sanoat tarmoqlarida kooperatsiya asosida tayyor mahsulotlar ishlab chiqarishni mahalliyashtirish tizimini takomillashtirish yo'llari	572
Xalilova Sevaraxon Alijon qizi	
Moliyaviy barqarorlikning asosiy ko'rsatkichlari va ularning tahlili	578
Urmanbekova Iroda Farxodovna	
Tijorat banklarining mamlakat iqtisodiyotida tutgan o'rnini tahlil qilish	583
Kilicheva F.B., Mengnorov A.A., Bozorova O.R.	
Bog'dorchilik tarmog'ida klasterlarni joriy qilishda yevropa tajribasini qo'llash imkoniyatlari	591
Ergashov Ulug'bek Zoxidjonovich	
To'qimachilik klasterlarini boshqarishda xorijiy mamlakatlar tajribasi	598
Mansurov Saidxo'ja Kamalovich	
Barriers to tourism infrastructure development in uzbekistan: a critical analysis	605
Sarvinov Shodmonova	
Xalqaro bozorda qishloq xo'jaligi mahsulotlari raqobatbardoshligini oshirish	609
Mengnorov Almardon Abdirahmonovich	
O'zbekiston respublikasida infratuzilma loyihalarini amalga oshirishdagi risklarni boshqarish	620
Yusupova Zilola Ismoiljon qizi	
Korxonaning iqtisodiy barqarorligiga erishishning zamonaviy tendensiyalari	626
Iminova Nargizaxon Akramovna	
Qishloq joylari maishiy xizmat ko'rsatish sohasida axborot resurslaridan samarali foydalanish	631
Xamdamov Eldor Toshmurovich	
Meva-sabzavotlar eksportida transport koridorlari va vositalarini tanlash xususiyatlari	636
Yusupov Muxiddin Soatovich	
Рынок рабочей силы в узбекистане и ее воспроизводство	644
Шакиров Амаль Улугбекович, Камилова Наргиза Абдукахаровна	
Деньги и их функции в экономике	650
Мурадиллаев Мансур Мехроживич, Камилова Наргиза Абдукахаровна	
Развитие сельского хозяйства в узбекистане	654
Махмудов Алишер Мухтарович, Камилова Наргиза Абдукахаровна	
Инвестиции и инновации в химической промышленности узбекистана: современные тенденции и перспективы	658
Хусаинов Равшан Рахимович, Султанходжаев Аманулла Асадуллаевич	
Tijorat banklari aktivlarini boshqarishni takomillashtirish	666
Mardonova Shoxsanam Baxodirovna	
Definition of agritourism as a multifunctional development in rural areas	672
Aktamov Olimjon Abdugani ugli	
Kameral soliq tekshiruvida smart texnologiyalarini ma'lumotlarini soliq organlarining ma'lumotlar bazasida shakllanishi	680
Qurbonov Muxiddin Abdullaevich	
Проблемы регулирования государственно-частного партнерства и рекомендации по их решению (на примере безработицы в республике узбекистан)	687
С.Э. Холмуратов	



Автоматизация аудиторских процедур с использованием искусственного интеллекта.....	692
Ходжарахманова Назира Бахтияр кизи	
Past karbonli iqtisodiyotga o'tish zaruriyati va uning omillari.....	701
Valiyev Axliddin Aropitdinovich	
Yengil sanoatda zamonaviy tikuv mashina-kichik robotlarning mexanizmlarini mukammallashtirish	705
Sirojova Muxabbat Sodiq qizi, Kurbanov Fazliddin Aminovich	
Jismoniy shaxslar daromadlarini soliqqa tortish tizimining institutsional va iqtisodiy asoslari	710
Kuzieva Nargiza Ramazanovna, Bobomuratova Manzura Panji qizi	
Foyda solig'i bo'yicha bo'nak to'lovlarni to'lash tartibi	717
Yangieva N.S.	
Kichik biznes va tadbirkorlik subyektlarini soliqlar vositasi qo'llab-quvvatlashning amaldagi holati	722
Turanboyev Boburjon Qodirjon o'g'li	
Motivation, goal-setting, and organizational performance: a case study from uzbekistan's chemical industry	726
Mamataliev Anvar Ergashevich, Bobur Urinov	
Применение искусственного интеллекта при организации налогового администрирования узбекистана	733
Н.А. Артиков	
Ayollar tadbirkorligini rivojlantirish zaruriyatini keltirib chiqaruvchi omillar.....	737
Sharofiddinova Gulnoza Iloxmonovna	
Raqamli texnologiyalarning tijorat banklari samaradorligiga ta'siri	745
Maksudov Avazbek Ulug'bek o'g'li	
Suv tanqisligi sharoitida yashil iqtisodiyotni rivojlantirish asoslari	750
Qosimov Maxamatjon Sulaymanovich	
Rivojlanayotgan iqtisodiyotda raqamli va raqamli bo'lmagan korxonalar tahlili	761
Raxmonov Nodirjon Raxmonjon o'g'li	
Aholining o'rtacha umr ko'rish yoshini o'zgarishi sharoitida keksalarning ijtimoiy ta'minotiga xavflarning ortishi.....	767
To'irov Shohboz Ziyodullo o'g'li	
Oliy ta'lim tizimida moliyaviy nazorat samaradorligini ta'minlash ichki nazorat xizmatlari	773
Xaydarov Baxrom Xolmuradovich	
Moliya bozorida xususiy banklar faolligini ta'minlash istiqbollari	777
Abduqahhorov Asilbek Ahror o'g'li	
Budjet daromadlari ijrosini ta'minlashda soliqlar hisobi va tahlilining ahamiyati	782
Abdullaev Abror Bozarboevich	
Aholi daromadini oshirish yo'llari.....	803
Shadmanov Baxodir Sherkulovich	
Tourism and regional identity in Uzbekistan: balancing heritage and development	808
Raximova Nilufar Aminovna, Abdukholikova Farida Erkinjon qizi	
O'zbekiston sanoat korxonalarining fond bozorida ishtiroki tahlil va muammolari.....	815
Igitov Jurabek Kuzibekovich	
O'zbekistonda davlat-xususiy sheriklik loyihalarini moliyalashtirish va amalga oshirish tahlili	823
Karabaev Sanjar Abdusamatovich	
Globalashuv sharoitida milliy korxonalarning eksport salohiyatini boshqarish masalalari	832
Qodirov Humoyun Tolibjon o'g'li	
Бизнес-планирование и прогнозирование деятельности организации.....	836
Алимов Бехзоджон Наврузжонович	
Farg'ona vodiysida ekoturizm – kambag'allikka qarshi kurashning yangi imkoniyatlari	840
Soliyeva Nilufar Muxtorjon qizi	
Aholi turmush darajasi baholash bo'yicha dasturiy ta'minot ishlab chiqishda horij tajribasini o'rganish	844
Tursunov Farxod Baxodir o'g'li	
Mintaqa aholi turmush farovonligiga ta'sir qiluvchi omillar tasnifini ishlab chiqish.....	848
Xodjanijazov Shohruh Yuldashevich	
Xususiy oliy ta'lim muassasalari menejmentining nazariy jihatlar va o'ziga xos xususiyatlari.....	856
Karimov Ulug'bek Usmonovich	



Infratuzilma va bozor infratuzilmasi tushunchalarining nazariy tavsifi	861
G'aniyev Botir Baxtiyorovich	
Повышение инвестиционной привлекательности – важное условие повышения конкурентоспособности предприятий.....	865
Каримова Дилафруз Садирдин кизи	
Yevropa ittifoqi davlatlari tijorat banklarining soliq to'lovlarini amalga oshirish tartibi	870
Komolov Odiljon Sayfidinovich	
Boshqaruvda innovatsiyalarni hisobga olgan holda agrokorxonalarni davlat tomonidan rag'batlantirishning zamonaviy yondashuvlari	878
Shaniyazova Zamira	
Практические аспекты применения статистических методов контроля качества на предприятиях.....	883
Усманов Илхом Ачилович, Усманов Фарзод Шохрухович	
Yashil iqtisodiyot sharoitida iqtisodiy o'sishning yangi paradigmalarini shakllantirish: nazariy asoslar va amaliy talqinlar.....	891
Alimova Guzal Abduraximovna	
Xizmat ko'rsatish korxonalari faoliyati samaradorlik ko'rsatkichlarining nazariy va metodologik tahlili	895
Qo'ziyoyev Boxodir Azzamboy o'g'li	
Kutubxonalarda raqamli iqtisodiyot sharoitida biznes-modellarni ishlab chiqish.....	900
Ernaqulov Sunnatillo Nurali o'g'li	
To'g'ridan-to'g'ri sug'urtalash operatsiyalari bo'yicha xarajatlarni xalqaro standartlar asosida hisob va hisobotda aks ettirish uslubi-yatini takomillashtirish	905
X.A.Raximov	
Kameral soliq tekshiruvda smart texnologiyalarini ma'lumotlarini soliq organlarining ma'lumotlar bazasida shakllanishi.....	910
Ergashev Uyg'un Jabborovich	
Obligatsiya moliya bozori instrumenti sifatida, milliy obligatsiyalar bozori	916
Avezov Ibrohim Ilxomovich, Yaxshiboyev Jahongir Abdalimovich	
Barqaror rivojlanish doirasida ekologik, ijtimoiy va korporativ boshqaruv (ESG) ko'rsatkichlarining yashil texnologiyalar innovatsiyasiga ta'sirini baholash.....	921
Meliqo'zieva Dilrabo Muxitdin qizi	
Yashil iqtisodiyot – barqaror taraqqiyotga olib boruvchi yo'l.....	925
Xalilova Aziza Rustamovna	
Научно-теоретические основы экономической и эколого-экономической эффективности предприятий горнодобывающей промышленности.....	930
Раматов Зафарбек Жуманиязович	
Xitoyda eksport faoliyatini tashkil etishning o'ziga xos xususiyatlari.....	938
D.E.Qarshiev	
Kichik sanoat zonalarida investitsion jozibadorlikni oshirishni investitsion faollikka ta'siri.....	943
Mannapova Shaxnoza Elshodovna	
Mahalla institutining samaradorligi tahlili: so'rovnoma yondashuvi	947
Bahriddinov Viqorjon Akbar o'g'li	
Формирование человеческого капитала в условиях демографических изменений: опыт и перспективы для узбекистана.....	955
Дониерова Фотимабону Алишер кизи	
Farmasevtika kompaniyalari raqobatbardoshligini oshirishda marketing strategiyalaridan foydalanish yo'nalishlari	962
Baxrombek Bobojonov	
“Hududlarda sug'urtaga bo'lgan talabning ekonometrik tahlili” bekberganova mohira ravshonbekovna	967
O'zbekiston Milliy universiteti	
O'zbekiston va xalqaro amaliyotda raqamli marketing vositalaridan foydalanish: muammolar va yechimlar	973
Uzoqova Dilnoza Yusuf qizi	
Условия эксплуатации и экологическая безопасность автотранспортной системы на основе энергосберегающих технологий	978
Мамасалиева Мукаддас Ибадуллаевна	
O'zbekiston tibbiyot muassasalarida moliyaviy resurslardan foydalanishda xorijiy tajribalarni qo'llash.....	982
Elmurodov G'ayratjon Abdumurodovich	



Buxgalteriya hisobining samaradorligini oshirish yo'llarida zamonaviy yondashuvlar va innovatsiyalar	987
Sattorov Mirjahon	
Особенности маркетинговых стратегий в условиях ограниченных ресурсов и узкой потребительской аудитории	991
Дебердиев Анвар	
DEbitorlik va kreditorlik qarzlarini auditini rejalashtirish masalalari.....	995
Tulovov Erkinjon To'liqin o'g'li, Ibragimova Iroda Rashid qizi	
Инвестиционная программа узбекистана по привлечению иностранных инвестиций	1000
Камилова Наргиза Абдукажоровна, Бекмуратов Шухрат Даулетмуратович	
Turistik mahsulotni shakllantirishda turistlar hayoti xavfsizligini ta'minlash.....	1005
Raxmonov Siyovush Turob o'g'li	
Uglerodsiz energiyaga o'tishda o'zbekistonning yashil strategiya yo'l xaritasining integratsiyasi va ta'siri.....	1011
Nuraliyeva Komila Sanakulovna	
Цифровая устойчивость регионов: применение аналитики больших данных для оценки и управления экологическими рисками	1016
Маликов Шохрух Шокирович, Камалов Шухрат Камалович	
Разработка риск-ориентированной модели внутреннего контроля предприятия на этапе планирования налогов в условиях дистанционного налогового мониторинга	1024
Галеева Н.Н., Э.А.Халикова, Абдусаломова Гулчеҳра Мирзо кизи	
Анализ результатов инструментальных методов исследований у детей с врожденными пороками сердца	1029
Мухаммадиева Лола Атамурадовна	
Barqaror iqtisodiy o'sishni ta'minlashda monetar omillardan samarali foydalanish yo'nalishlari.....	1036
Uskenbaeva Dilnoza Boxodir qizi	
Факторы повышения эффективности управления в государственном секторе.....	1043
Махмудова Севара Улугбековна	
Soliq organlari va soliq to'lovchilar o'rtasidagi munosabatlarning yangi tizimi sharoitida soliq nazorati	1048
Rajabbaeva Dildora Zakirovna, Aripova Aziza Alisherovna	
Boshqaruv jarayonlarini tashkil etishning xorijiy mamlakatlar tajribasi.....	1053
Jo'rayeva Niginaxonim Xursand qizi	
Jahonda eksportni qo'llab-quvvatlash amaliyoti.....	1057
Xudoynazarov Sherzod Ismoilovich	
Raqamli moliyaviy texnologiyalarni korxona darajasida joriy etish orqali moliyaviy barqarorlikka erishish strategiyasi	1063
Soibov Nozimbek Faxridin o'g'li	
Применение методов PMBOK в управлении рисками проектов	1070
Гулираъно Носирова Абдулазиз кизи	
Tadbirkorlik faoliyatini rivojlantirishda aholi farovonligining o'rni va ahamiyati	1073
Bobaev Isroiljon Abdinabievich	
Вопросы инновационных инвестиций в контексте международной экономической интеграции	1078
Шарипов Бахтиёр Михлибаевич	
Yashil iqtisodiyotga o'tishning nazariy va amaliy jihatlar hamda tendensiyalari.....	1083
Samiyev Abdurashid Qaxramonovich, Shermuxammedov Begzodjon Usmonovich	
Tijorat banklarida muammoli kreditlar samaradorligini ta'minlash yo'llari.....	1087
Nazarov Qilich Xolmuradovich	
Improving the organizational and economic mechanisms for the development of tourism in the republic of karakalpakstan	1092
Tleumuratov Baxadir Genjemuratovich	
O'zbekistonda tumanlar barqaror iqtisodiy rivojlanishini ta'minlash yo'llari (Surxondaryo viloyati misolida).....	1097
Qosimova Nodira Saidovna	
Innovatsion iqtisodiyotni shakllantirishning asosi sifatida innovatsiyalar.....	1102
Azizova Maliha Farrux qizi	



Влияние инвестиций на инновационное развитие и повышение конкурентоспособности экономики узбекистана	1106
Максудова Шахзода	
Возможности снижения затрат на логистику за счет цифровых технологий	1112
Олимова Бахора Шухратовна	
Yashil texnologiyalar va ularning iqtisodiy tizimga ta'siri	1116
Sultonov Omon Juma o'g'li	
Iqtisodiy o'sishning makroiqtisodiy faktorlari va ularning ta'siri	1121
Zuvaydullaev Nematullo Oybek o'g'li	
Роль управления производством в условиях модернизации экономики	1125
Гулов Мухтор Очилович	
Iqtisodiyotni raqamlashtirish sharoitida sun'iy intellekt texnologiyalarining o'rni va ahamiyati	1129
To'rayev Shavkat Shuxratovich	
Роль цифрового маркетинга в продвижении туристических направлений	1136
Муродова Наргиза Уткировна	
Развитие финансовых рынков в странах снг: проблемы и перспективы	1140
Рузиев Зафар Икрамович, Каримов Ислон Ураз угли	
Современные инструменты продвижения бренда в условиях цифровой экономики	1145
Темирова Феруза Сагдуллаевна	
"Raqamli asrda axborot xavfsizligi: it texnologiyalar bilan xavfsizlikni ta'minlash yo'llari"	1149
Sherzod Rajabov	
Государственное регулирование инвестиционной деятельности: проблемы и направления совершенствования	1152
Шухрат Турсунов, Икромов Хасан Зафарович	
Economic incentives and barriers to sustainable transition in agribusiness: a comparative study of organic and conventional farming systems	1157
Mubina Toirova	
Цифровая трансформация банковской системы узбекистана: анализ внедрения fintech-решений в государственных банках	1162
Абдурахимова Дилора Каримовна	
Ta'lim muassasalaridagi ba'zi jihatlar	1167
A'zam Qutbiddin A'zam-zoda	
Klasterlar hisob siyosatida boshqaruv hisobining metodologik asoslari	1173
Toshpo'latov Azizbek Shermuxamadovich	
Egri soliqlarning mohiyati, genezisi va rivojlanish tendensiyalariga oid nazariy munozaralar xususida	1179
Shodiyev Olimjon Abduraxmonovich	
Ekologik mehmonhona faoliyatini rejalashtirish maqsadlari va vazifalari	1186
Abidova Dilfuza Igamberdievna	
Budjetlashtirish bo'yicha tashkiliy va uslubiy yondashuvlar tahlili.	1195
Xoshimov Baxrom Baxadirovich	
Investitsiya loyihalarining iqtisodiy va moliyaviy samaradorligini oshirish istiqbollari	1200
Jo'rabekova Xumora Muzaffar qizi, Saidov Rasul Boltabayevich	
O'zbekistonda nodavlat notijorat tashkilotlarini moliyalashtirish manbalarining tahlili	1204
Aliyev Arslon Salom o'g'li	
O'zbekistonda turizm sohasining iqtisodiy ko'rsatkichlarini statistik tahlil qilish	1213
Jumanova Zilola Tuychiyevna	
Xorijiy davlatlarda boylik solig'i va uning ijtimoiy-iqtisodiy ahamiyati	1219
Ruziyev G'anisher Usarovich	
Yer fondi va undan samarali foydalanishning nazariy asoslari (Samarqand viloyati misolida)	1225
Xoshimova Sevara Baxromovna	
Iqtisodiy-ekologik tizimlarni boshqarishga ta'sir etuvchi omillarning ilmiy asoslari	1229
Kuldoshev Asliddin Tursunovich	
Влияние финтех-услуг на финансовую инклюзию в сельских регионах узбекистана	1236
Абдурахимова Дилора Каримовна	
Surxondaryo viloyati sanoat sohasining asosiy ko'rsatkichlari tahlili	1240
Kuvanchiyeva Mehriniso Davlyatgeldi qizi	



A critical evaluation of strategic management's role in promoting sustainable development in Uzbekistan	1245
Ismatova Mahliyo	
O'zbekistonda turizm xizmatlari eksportini oshirishda zamonaviy infratuzilma va texnologiyalarning integratsiyasi	1251
Akmal Bakhromov	
Trends and reforms of corporate governance in state-owned enterprises	1257
F.Djalilov	
Переоценка долгосрочных активов в нефтегазовой промышленности и определение финансового результата от переоценки	1269
Махкамова Саида Гайратова	
Oziq-ovqat mahsulotlari korxonalarini integratsiyalashuv jarayonlarini boshqarish samaradorligini oshirish	1275
Xojiev Ibroxim Ikramovich	
Sug'urta kompaniyalari moliyaviy barqarorligini ta'minlashning muhim shartlari	1280
Allanazarova B.K.	
P2P lending and crowdfunding as alternative sources of financing for small business in Uzbekistan	1286
Abdurakhimova Dilara Karimovna	
O'zbekistonda soliq nazoratining huquqiy va tashkiliy asoslarini takomillashtirish yo'llari	1290
Kuziyeva Nargiza Ramazanovna, Oymatova Gulinur Mirjamolovna	
Applications of hyperbolic geometry in physics and biology	1295
Khaknazarova Khurshidabonu Kenjaevna, Otakulova Rukhshona Akram kizi	



APPLICATIONS OF HYPERBOLIC GEOMETRY IN PHYSICS AND BIOLOGY

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Abstract: Hyperbolic geometry, with its unconventional properties, has been playing an important role in modern science and technology. The main difference of this geometry - the negative curvature of space - allows for a deeper understanding and modeling of complex systems in the real world. On this basis, it can be said that hyperbolic geometry is an important concept that is actively used in solving real-life problems, in addition to fundamental theory.

This article will cover in detail the main applications of hyperbolic geometry in various sciences and fields, their working mechanisms, real-life examples, and scientific foundations.

Key words: Hyperbolic geometry, cosmology, biology, architecture, artificial intelligence, cryptography, theory of relativity.

Annotatsiya: Giperbolik geometriya o'zining noan'anaviy xususiyatlari bilan zamonaviy fan va texnologiyalarda muhim o'rin egallab kelmoqda. Bu geometriyaning asosiy farqi — fazoning manfiy egrilikka ega bo'lishi — real dunyodagi murakkab tizimlarni chuqurroq tushunish va modellashtirish imkonini beradi. Shu asosda aytish mumkinki, giperbolik geometriya bugungi kunda fundamental nazariyadan tashqari, real hayot muammolarini hal qilishda faol ishlatilayotgan muhim konsepsiyadir.

Mazkur maqolada giperbolik geometriyaning turli fan va sohalardagi asosiy tatbiqlari, ularning ishlash mexanizmlari, real hayotdagi namunalari hamda ilmiy asoslari batafsil yoritiladi.

Kalit so'zlar: Giperbolik geometriya, kosmologiya, biologiya, arxitektura, sun'iy intellekt, kriptografiya, nisbiylik nazariyasi.

Аннотация: Гиперболическая геометрия с ее нетрадиционными свойствами играет важную роль в современной науке и технике. Главное отличие этой геометрии - отрицательная кривизна пространства - позволяет глубже понимать и моделировать сложные системы в реальном мире. Исходя из этого, можно сказать, что гиперболическая геометрия является важным понятием, которое активно используется в решении реальных задач, помимо фундаментальной теории.

В этой статье будут подробно рассмотрены основные применения гиперболической геометрии в различных науках и областях, их рабочие механизмы, реальные примеры и научные основы.

Ключевые слова: Гиперболическая геометрия, космология, биология, архитектура, искусственный интеллект, криптография, теория относительности.

INTRODUCTION

In the history of mankind, the development of the science of geometry has been of incomparable importance in understanding nature, modeling it, and solving practical problems. Hyperbolic geometry, which emerged in the 19th century as an alternative to the strict postulates of Euclidean geometry, which had been recognized as the basic geometry for centuries, opened up new horizons in the development of science. In this type of geometry, such features as the number of parallel lines being multiple and the sum of the interior angles of triangles being less than 180° , are fundamentally different from Euclidean space.

We have built a world of mostly straight lines - the houses we live in, the skyscrapers we work in, the streets we walk on in our daily commute, etc. It is an alternative to the Euclidean geometry we learn in school,



which involves lines, shapes, and angles on a flat surface or plane. In hyperbolic geometry, the plane doesn't have to be so flat.

LITERATURE REVIEW OF THE TOPIC

Hyperbolic geometry (also known as Lobachevsky geometry or Bolyai–Lobachevsky geometry. The term “hyperbolic geometry” was introduced by Felix Klein in 1871.) Hyperbolic geometry, also known as Lobachevsky geometry, describes the geometry of negatively curved surfaces. It is a generalization of Euclidean geometry in which the parallelism axiom is violated. That is, there are infinitely many parallel lines that lie outside a straight line and never intersect it.

Hyperbolic geometry is a special field of mathematics that differs from Euclidean geometry. Hyperbolic space and its properties help us understand complex systems and structures in real life. Below are some of the applications of hyperbolic geometry in various fields and its role in real life.

RESEARCH METHODOLOGY

The author used scientific abstraction, comparative analysis, induction, and deduction methods in the article.

ANALYSIS AND RESULTS

Applications of hyperbolic geometry in biology

Hyperbolic geometry is used in biology as an effective tool for modeling the structure and dynamics of highly complex systems, especially biological networks and systems. Hyperbolic geometry in biology:

When analyzing changes in signaling between cells and the spread of viruses, the subtle dynamics of interactions are modeled using hyperbolic geometry.

The geometric shape of plants, i.e. leaves or branches, and their adaptation to their environment are analyzed based on hyperbolic geometry. Also, some bacteria and fungi live in hyperbolic space during their growth.

Biological relationships and hierarchies between higher-level organisms are described based on a hyperbolic network, which enables efficient analysis of interactions.

Using hyperbolic space, physical chemical processes between molecules and particles, as well as their energy and material exchange, are analyzed.

Biological systems can use hyperbolic geometry to optimize molecular interactions and synthesis processes, particularly in the field of synthetic biology.

The interactions between microorganisms and their role in the ecosystem are analyzed using a hyperbolic network, which helps to understand how they function in the ecological environment. The interactions between microorganisms and their role in the ecosystem are analyzed using a hyperbolic network, which helps to understand how they function in the ecological environment.





Hyperbolic geometry describes the properties of saddle-shaped surfaces with negative curvature. These surfaces arise in the theory of relativity due to the curvature of space-time due to mass.

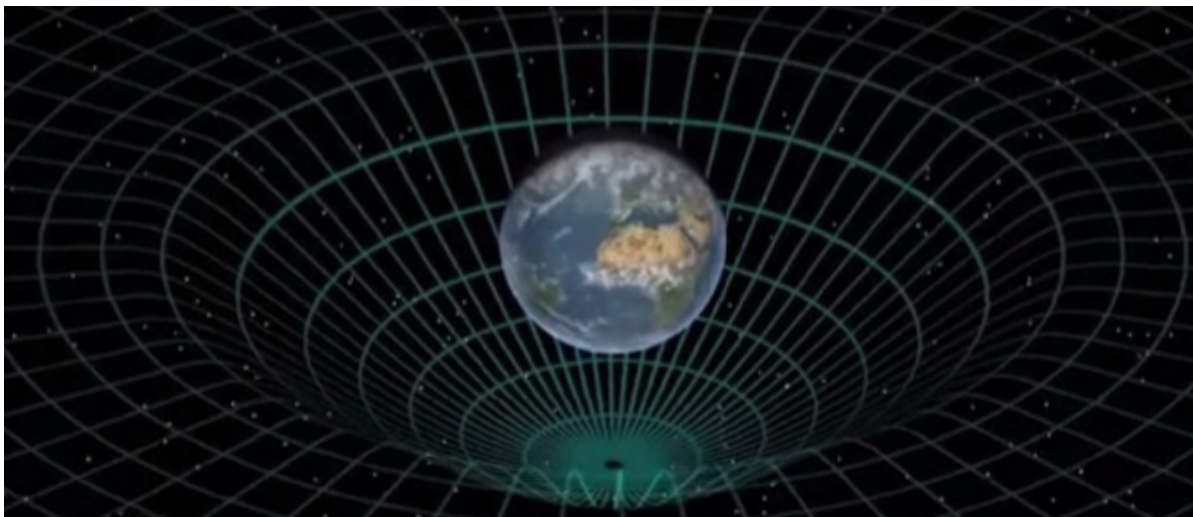
Gravity causes elliptical curvature. Any repulsive energy in free space causes hyperbolic curvature.

The overall geometry of the observable universe has been measured to within 1% of Euclidean, meaning that the universe's "positive curvature" and "negative curvature" sources largely cancel each other out. However, this measurement does not rule out the possibility that the universe has hyperbolic or elliptical geometry on scales 100 times larger than the observable universe.



Applications	Commentary	Examples
In quantum physics	In quantum physics, hyperbolic geometry is used to model many-body systems. Many-body systems are systems that involve the interaction of several quantum states. Hyperbolic geometry can be used to determine the energy states and spectral ranges of such systems.	Hyperbolic networks allow the structure and energy states of quantum systems to be calculated precisely. This is necessary, for example, for studying quantum gravity and interactions.
In cosmology	In cosmology, hyperbolic geometry is used, for example, to explain the theory of inflation. Inflation is a period of very rapid expansion of the universe, and hyperbolic geometry is used to model this process.	The cosmological alpha attractor model uses hyperbolic geometry to help preserve the symmetric structure during inflation. This approach is consistent with the Planck data and is used to determine the spectral index of inflation.
Quantum energy teleportation	Hyperbolic geometry allows quantum energy to be teleported over long distances. In hyperbolic networks, the energy distribution grows exponentially, which helps in the efficient transfer of energy over long distances.	Hyperbolic networks enable the transmission of quantum energy over long distances and create the necessary tools to control energy flows in large quantum networks.
phase models	Hyperbolic geometry is used in phase modeling and spatial evolution analysis, where hyperbolic spaces allow for a precise description of the motion and change of a system.	Physical systems in space and the structure of the cosmic web are modeled using hyperbolic spaces, which allows us to better understand the processes of the expansion of the universe and the change in time.

Again, hyperbolic geometry is used in many areas of physics and cosmology, and explains black holes and the theory of relativity.



In astrophysics, hyperbolic geometry is used in the study of the structure of the universe and its dynamics:

- Cosmic Structures: Galaxies and their interactions are modeled using hyperbolic geometry. This helps to understand intergalactic distances and their motion.

- Black holes and neutron stars: Hyperbolic geometry is used to study the spatial properties of extreme objects such as black holes and neutron stars.

In general relativity, the force of gravity bends space and is described by hyperbolic geometry. This helps us understand the effects of mass on space and the way time changes.

Hyperbolic geometry is used to model the expansion and structure of the universe. This allows us to study the geometric properties of the universe and its evolution.

Hyperbolic geometry is important in forming the mathematical foundations of quantum field theory, which helps us understand the interactions between particles and fields.

Hyperbolic spaces are used to describe quantum states, especially in high-dimensional systems. This helps to understand the complexity of quantum systems and their interactions.

Hyperbolic geometry helps in modeling the interactions between electromagnetic fields and particles. This helps in understanding the motion of particles and electromagnetic forces.

CONCLUSION.

The future of hyperbolic geometry in physics and biology:

Hyperbolic geometry opens up new possibilities for deeper study of the brain and neurological systems, understanding its structure, and identifying connections between neurons.

Hyperbolic geometry will be used to deepen scientific research by analyzing genomic data and biological network relationships. Hyperbolic spaces will allow us to identify new genetic mutations and study their effects on biological systems.

In space exploration, hyperbolic geometry plays an important role in analyzing the geometric spaces of black holes and studying their internal structure. This is especially helpful in creating spatially-adapted models and discovering changes.

Conclusion and suggestions

Hyperbolic geometry is not only used in physics and biology. Hyperbolic geometric shapes serve as the basis for creating decorative compositions and optical illusions in art, and in mathematics for developing new branches of geometry. In everyday life, its traces can be seen in many areas, such as Internet network structures, security algorithms, and navigation systems.

While most of the evidence on a large scale points to Euclidean structure, there is some startling evidence that we may simply live in a hyperbolic world.

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