Book of Abstracts

The 8th International Conference

on

Mathematics and Mathematics Education

Theme: Mathematics for Social Impact

May 22-23, 2025
Dilla University, Ethiopia

Main Organizing Committee

Book of Abstracts

The 8th International Conference on Mathematics and Mathematics Education + the 2nd National Mathematical Olympiad

Under the Theme

"Mathematics for Social Impact"

Organized by Dilla University in Collaboration with Ethiopian Mathematics Professionals Association (EMPA)

May 22-23, 2025

Dilla, Ethiopia

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Message from the Vice President for Research and Technology Transfer

Honorable guests, esteemed scholars, respected colleagues, and distinguished participants,

It is with immense pleasure and deep gratitude that I welcome you to this esteemed gathering-the 8th Conference of the Ethiopian Mathematics Professionals' Association (EMPA). Hosted with pride by Dilla University (DU) in collaboration with EMPA, this event is made possible through the invaluable support of our distinguished stakeholders. For the past **12 years**, Dilla University has remained committed to advancing education by hosting its annual research conference on Education. In 2023, the university successfully convened its 11th edition, and this year, it takes great pride in dedicating the conference to Mathematics, recognizing its pivotal role in academic excellence and societal progress.

In this dynamic academic setting, we gather not only to celebrate mathematics but to examine its profound influence on society. Amid ongoing challenges in computational education in Ethiopia and their potential impact on national development, this conference serves as a timely and essential forum. It offers a vital space for addressing key issues, fostering innovation, and shaping the future of mathematical and computational learning to drive national progress. Mathematics is more than just numbers, formulas, and theorems-it is the bedrock of innovation, the catalyst for development, and a force for transformative change. This year's theme, **Mathematics for Social Impact**, underscores the far-reaching significance of mathematics beyond academia. It fuels economic growth, advances technology, enhances education, and provides solutions to real-world challenges.

As we embark on these two days of thought-provoking discussions, groundbreaking research presentations, and meaningful networking, I encourage each of you to participate actively, inspire others, and explore new horizons in mathematical applications for the betterment of society. Through our collective knowledge and expertise, we can shape a future where mathematics remains a driving force for innovation and societal progress. Once again, welcome to Dilla University, welcome to this distinguished conference, and welcome to a new era where mathematics bridges gaps, transforms communities, and sparks innovation.

Finally, I extend my sincere gratitude to the conference organizers, collaborators, keynote speakers, paper presenters, participants, the DU community, Dilla town administration, and the security team for their dedication and collective efforts in making this event a resounding success.

Thank you, and let's embark on this exciting journey together!

Habtamu Temesgen (PhD, Associate Professor)
Vice President, Research & Technology Transfer
Dilla University

Message from the President of EMPA

Dear colleagues and friends,

On behalf of the Ethiopian Mathematics Professionals Association (EMPA), it is my honor to welcome you to this landmark event, uniting scholars, educators, and students under the theme "Mathematics for Social Impact."

Founded to expand research in mathematics and mathematics education, EMPA is committed to fostering idea exchange through conferences, publications, and collaborations. We advocate for the critical role of mathematics in national development and work tirelessly to support the production of qualified graduates who will drive innovation across sectors.

This conference celebrates Ethiopia's growing leadership in global mathematics, from cutting-edge research to start of Olympiad excellence. The diverse sub-themes-from computational science to STEM education-reflect our mission to support mathematics for sustainable progress.

We extend our heartfelt appreciation to our esteemed partners, keynote speakers, the Ministry of Education's STEAM Desk, STEAM Power, Ethiopian universities, Diaspora mathematicians, and all our national and international stakeholders. Your unwavering support is nurturing the next generation of problem-solvers while honoring Ethiopia's rich mathematical heritage, rooted in contributions spanning from ancient calculation methods to contemporary breakthroughs.

As you engage with the ideas presented in these abstracts, may they ignite collaboration, spark innovation, and inspire transformative action. Together, let us continue shaping a future where mathematics empowers every sector of society.

Samuel Asefa Fufa (PhD)
President, Ethiopian Mathematics Professionals Association (EMPA)
Addis Ababa University

Message from the Head of STEAM Desk

Dear Esteemed Participants,

Warm greetings to all distinguished guests, educators, students, and partners gathered here today for this inspiring Mathematics Conference and Olympiad organized in my former university Dilla University by Ethiopian mathematics associations, Ministry of education STEAM desk and Addis Ababa University. It is an honor to witness this vibrant assembly dedicated to the celebration of mathematics-a foundational pillar of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education.

Today, we come together to celebrate mathematics—not just as a subject, but as a vital tool for innovation, problem-solving, and progress. Within the STEAM framework, it serves as the backbone, empowering learners with logical reasoning, analytical thinking, and precision.

I am honored to address you that STEAM is more than an academic approach; it is a transformative force that nurtures creativity, critical thinking, problem-solving, and innovation among learners.

Mathematics plays a crucial role in the development of any nation. It drives technological advancement, supports scientific research, strengthens economic planning, and enhances decision-making across all sectors. By nurturing mathematical excellence in our youth, we are investing in a future generation equipped to lead, innovate, and transform their communities and the world.

Let this conference and Olympiad ignite curiosity, inspire collaboration, and pave the way for a stronger, knowledge-based society in STEAM.

May God bless you!

Thank you

Mr. Tadesse Teressa Deme
Ministry of Education STEAM desk Head
Addis Ababa

Message to the National Mathematical Olympiad Contestants

Dear Contestants,

It is an absolute pleasure to extend my message on this remarkable day of the 8th International Conference on Mathematics and Mathematics Education, held under the theme ***Mathematics for Social Impact.*** This conference is particularly special, as it includes the 2nd National Mathematical Olympiad-a competition aimed at gathering outstanding high school students and preparing them for the upcoming Pan- African Mathematical Olympiad. The Olympiad is organized by EMPA, in collaboration with Ethiopia's Higher Education Institutions with the purpose and objectives of promoting Mathematics, Identify Talent and International standards.

Mathematics is often perceived as a dry and difficult subject-filled with complex calculations that seem disconnected from creativity and discovery. Many students and members of the public find its terminology intimidating, often reacting with frustration or disinterest. However, whether we realize it or not, mathematics surrounds us in everyday life-it shapes the world we live in, influencing science, technology, and problem-solving in profound ways. Some students, like yourselves, embrace mathematics dynamically, pushing its boundaries in exciting ways.

The Mathematical Olympiad serves as a platform to assess students' mathematical talents, fostering problem-solving, critical thinking, and innovation. Unlike regular school exams, the Olympiad unveils the deeper meaning behind mathematics, nurturing excellence, building strong foundations, offering global recognition, and paving the way for promising careers.

It is important to recognize the prestige of the International Mathematical Olympiad (IMO)-the world's most renowned math competition for pre-university students. Established in 1959 in Romania, the IMO has since grown to include more than 100 countries, although Ethiopia has yet to participate-a gap we must strive to close. The first-ever East African Mathematical Olympiad, held online on February 20, 2023**,** marked a significant milestone, as Ethiopia participated alongside six other nations.

This year's Olympiad event features 6,142 students, competing in two screening phases, culminating in a final round where the top ten winners will be selected from 43 finalists. Your participation is invaluable and presents opportunities to: advance problem-solving skills, cultivate a passion for mathematics, gain networking and global exposure, access scholarship opportunities, boost confidence and self-esteem and open doors to academic and career success. I strongly believe that this event, along with your commitment, will significantly contribute to EMPA's efforts to secure Ethiopia's participation in the IMO in the near future.

Finally, I extend my sincere appreciation to universities, STEAM Desk-MoE, STEM power, Inc., Global Talent Fund, sponsors, Ethiopian Diaspora Mathematicians, coordinators, invigilators, and all individuals who have dedicated their time and effort toward the success of this Olympiad.

Wishing you all an enriching and rewarding competition!

Dereje Kifle Boku (PhD)
Math Olympiad Coordinator, EMPA

Message from the Dean of College of Natural and Computational Sciences

It is with great honor and deep appreciation that I welcome all participants to the 8th International Conference on Mathematics and Mathematical Education, hosted by Dilla University in collaboration with the Ethiopian Mathematics Professional Association (EMPA). This significant event, organized under the grand theme **"Mathematics for Social Impact"** stands as a testament to our collective commitment in advancing mathematical knowledge and its powerful role in addressing the challenges and opportunities facing our societies.

Mathematics, often described as the language of the universe, continues to play an essential role not only in the development of science and technology but also in driving evidence-based policy, sustainable development, and innovation in diverse sectors. At Dilla University, and particularly within the College of Natural and Computational Sciences, we remain dedicated to nurturing a vibrant academic community that upholds excellence in mathematical research, teaching, and public engagement.

This conference brings together scholars, educators, students, and practitioners from across the globe to share their research findings, exchange ideas, and foster collaborations. It also offers a platform for young researchers and graduate students to engage with global mathematical discourses, contributing to capacity-building in mathematical education and its real-world applications.

I extend my sincere gratitude to all presenters, participants, organizing committee members, and partners whose dedication and support have made this conference a reality. I hope that the discussions and connections forged here lead to impactful contributions in mathematics for the betterment of society.

I wish you a successful and inspiring conference experience.

Mr. Mathewos Hosiso Bade
Dean, College of Natural & Computational Sciences
Dilla University

Message from the Head of Department of Mathematics

Dear Esteemed Participants,

On behalf of the Mathematics Department at Dilla University, it is my great pleasure to warmly welcome you to the **8th International Conference on Mathematics & Mathematics Education (ICMME-2025)** and the **2nd Mathematics Olympiad**.

This year's theme, *"Mathematics for Social Impact,"* reflects our shared belief that mathematics is more than a discipline—it's a powerful tool for addressing global challenges and driving meaningful change in society. From healthcare and education to technology and the environment, mathematics continues to shape and uplift communities around the world.

At Dilla University, we are proud to host this important gathering and reaffirm our commitment to promoting the social relevance of mathematics. This conference serves as a dynamic platform to exchange ideas, build networks, and highlight innovations that can transform lives through the power of mathematical thinking.

The **Book of Abstracts** you now hold showcases a wide range of perspectives and contributions from researchers, educators, and practitioners dedicated to making a difference. I would like to extend my heartfelt gratitude to the organizing committee, our dedicated faculty and staff, and the broader university community whose collective effort made this event a reality.

We hope your time at Dilla University is both inspiring and impactful. May this conference spark fresh ideas, ignite collaborations, and further demonstrate the essential role of mathematics in building a better and more equitable world.

With warmest regards,

Mr. Birara Animut Getie
Head, Department of Mathematics
Dilla University

Keynote Speech-1: The Role of Mathematics Education on Enhancing Social Impact

Mulugeta Atnafu Ayele (PhD, Professor)*

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Abstract

Mathematics education plays a crucial role in enhancing social impact by encouraging economic development, promoting social equity, and empowering individuals with critical thinking skills and problem-solving abilities needed for informed decision-making in various aspects of life. By understanding and applying mathematical principles, individuals can contribute to sustainable development, address inequalities, and participate more effectively in a complex world. Therefore, the presentation focuses on eight steps such as: the role of mathematics in society; the objectives of teaching mathematics in Ethiopian schools; the research findings on teaching-learning mathematics in Ethiopia; alternative approaches in teaching mathematics using students' real-world experience; different areas of students' real-world experience in mathematics; data collection of students' real-world experience in mathematics; integration of students' real-world experience in school mathematics curriculum; and methods of teaching-learning students' real-world experience in mathematics.

Keynote Speech-2: Social Impact of Mathematics

Chernet Tuge Duressa (PhD, Professor)*

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Abstract

Mathematics has long been celebrated for its logical elegance and foundational role across scientific domains. However, in the context of global challenges framed by the United Nations Sustainable Development Goals (SDGs), there is a growing need to conceptualize and articulate the **social impact of mathematics**. This presentation explores how mathematics can be harnessed as a transformative tool for addressing real-world problems aligned with key SDGs—including good health and well-being (SDG 3), quality education (SDG 4), clean water and sanitation (SDG 6), climate action (SDG 13), and reduced inequalities (SDG 10). Through case studies in epidemic modeling, resource optimization, environmental risk assessment, and educational data analytics, we demonstrate how mathematical techniques—from dynamical systems to statistical inference and operations research—can inform policy, guide interventions, and promote equity. The talk also calls for a renewed sense of professional responsibility among mathematicians to engage with interdisciplinary teams, communicate insights to broader audiences, and prioritize research agendas that are ethically and socially responsive. By conceptualizing mathematics not only as a technical discipline but as a driver of sustainable development, we highlight its vital role in shaping a more just, resilient, and informed society.

Keywords: Social Impact of Mathematics, Sustainable Development Goals (SDGs), Mathematical Modeling, Climate Action, Public Health, Education Analytics, Equity, Applied Mathematics, Interdisciplinary Research, Ethical Engagement.

Plenary Talks

Plenary Talk-1: Research in Mathematics Education: Mathematics in Ethiopia

Abdulkadir Hassen[1] (PhD, Professor)

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Abstract

In this talk, we will explore the topics covered in mathematics education research, the role of mathematical organizations in promoting the research and publications. We will also address the current Ethiopian high school mathematics contents and suggest some points to discuss to improve the pedagogical presentation of the contents.

Plenary Talk-2: Polynomial Processes and their Applications to Stochastic Modeling

Johannes Assefa[1]

[1]Department of Mathematical Stochastics, TU Dresden, Germany
[1]Department of Mathematics, Addis Ababa University, Ethiopia

Abstract

We introduce a class of Markov processes, called m-polynomial, for which the calculation of (mixed) moments up to order m only requires the computation of matrix exponentials. This class contains affine processes, processes with quadratic diffusion coefficients, as well as Levy-driven SDEs with affine vector fields. Thus, many popular models such as exponential Levy models or affine models are covered by this setting. The applications range from statistical analysis of mRNA transcription to new techniques for option pricing and hedging. For instance, the efficient and easy computation of moments can be used for variance reduction techniques in Monte Carlo methods.

Panel 01: Pure Mathematics

P01-1: On Decomposition Number of Graphs

Samuel Asefa[1], Birhanu Gebrehanna[1*]

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Abstract

For an undirected labeled graph $G\,(V,E)$ with where V is vertex set and E edge set, a decomposition of G is defined to be a partition of V in to a clique (a complete subgraph) of the partition yields a connected, induced subgraph of G. In this paper we will show decomposition number of some well-known special families of graphs and their ties with Bell, Fibonacci and Lucas numbers, deletion contraction theorem, Finding bound for decomposition number of any undirected labeled graphs and decomposition number with some restriction.

Keywords: Bell, Fibonacci, Lucas numbers, Graph decomposition, deletion contraction

P01-2: Preideals in Hyper EQ-algebras

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Abstract

Borzooei et al. (2013) introduced Hyper EQ-algebras. Ganji Sffrar and Borzooei (2016) introduced filter theory on good hyper EQ-algebras and their properties. In this paper, we study (pre) ideals in Hyper EQ-algebras and their properties. More over by using (pre)ideals, we construct equivalence relation, congruence relation and quotient hyper EQ-algebras.

Keywords: EQ-algebras, (pre)ideals, hyper EQ-algebras, congruence relations.

P01-3: On Eccentric Connectivity Coindex of Graphs of some Fixed Parameters

Mesfn Masre*

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Abstract

Graph theory is applied to characterize chemical structures and in structure-property/activity relationships via topological indices. A topological index is a numerical value calculated from a molecular graph, representing the molecule's topology by atoms (vertices) and bonds (edges). Chemical graph theory employs these indices to relate molecular graph structure to properties or activities. For example, structural features like size, shape, branching, symmetry, bonding patterns, and atomic neighborhood in molecules are measured by topological indices. Eccentricity-based indices correlate well with physical and biological properties, showing predictive power, such as for anti-HIV activity. The eccentric connectivity coindex of a graph G is defined as the sum of the eccentricities of non-adjacent vertex pairs, equivalent to summing the product of each vertex's eccentricity and the difference between the graph's order minus one and its degree. This index relates to the eccentric connectivity index, which sums the eccentricities of adjacent vertex pairs. One core problem in topological indices is studying extremal properties and characterizing extremal structures. Studying the relation between topological indices and other graph invariants also helps researchers to better know the indices and find more internal information. Properties of eccentricity-based indices have been investigated extensively. Several bounds on the eccentric connectivity coindex for graphs of given parameters (order, size, diameter, radius) have been established. The eccentric connectivity coindex for graph operations has been investigated, and extremal problems for general, tree, unicyclic, and bipartite graphs have been examined. This work extends the study of the eccentric connectivity coindex for graphs and presents sharp lower bounds on it for graphs of given order in combination with vertex connectivity, edge connectivity, number of pendant vertices, number of cut edges, matching number, chromatic number, clique number, and vertex bipartitness. Furthermore, we present an upper bound on the eccentric connectivity coindex for graphs of given order and number of pendant vertices. All the extremal graphs are present as well.

Keywords: eccentric connectivity coindex; vertex connectivity; matching number; pendant vertices; cut vertices

P01-4: A Unique Fixed-Point Result in Dislocated Quasi-b- Metric Spaces

Jemal Yesuf *

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Abstract

This article establishes a unique fixed-point result for a continuous self-map that satisfies a contractive condition within the framework of dislocated quasi b-metric spaces. It demonstrates the existence and uniqueness of the fixed point, enhancing and generalizing several notable results from existing literature. Additionally, we include an example to support the main finding.

Keywords: Cauchy sequence, contraction mapping, self-mapping, dislocated quasi-b-metric space, fixed point.

P01-5: On Labeled Graph C*-algebras

Menassie Ephrem[1] (PhD, Professor)

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Abstract

Given a directed graph E and a labeling L, one forms the labeled graph C*-algebra by taking a weakly left--resolving labeled space (E, L, B) and considering a universal generating family of partial isometries and projections. In this work, we look at the ideals for a labeled graph C*-algebra when the graph contains sinks. Using some of the tools we build, we compute C*(E, L, B) when E is a finite graph.

P01-6: V-modules, SSI-modules and Idempotent Hereditary Pretorsion Module in the Class of $\sigma[M]$

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Abstract

A module M is called a V-module (cosemisimple module) if every simple module in $\sigma[M]$ is M-injective. A module M is an SSI-module if every semisimple module in $\sigma[M]$ is M-injective. The main objective of this talk is to prove that a module M is an SSI-module if and only if M is a locally noetherian V-module. We also prove that an R-module M over a commutative ring R is semisimple if and only if every hereditary pretorsion class in ptors-M is an idempotent radical.

P02-1: The Effectiveness of GeoGebra Software Integrated POGIL on Students Mathematical Proficiency in Geometry

Gizachew Belay*, Kassa Micheal (PhD) and Mulugeta Woldemichael (PhD)

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Abstract

The ability to make mathematical connections is crucial for meaningful learning in geometry, as emphasized by the National Council of Teachers of Mathematics (NCTM) Process Standards—Problem Solving, Reasoning & Proof, Communication, Connections, and Representations. However, conventional instructional methods often fail to foster these connections, resulting in fragmented learning experiences. This study investigated the effectiveness of integrating GeoGebra Software with Process-Oriented Guided Inquiry Learning (GGS-POGIL) in enhancing students' mathematical connection skills. POGIL, developed in the late 1990s by Rick Moog and colleagues at Franklin & Marshall College in the United States for chemistry education, offers a structured approach to guided inquiry, promoting collaboration and deep conceptual understanding. Unlike general inquiry-based learning, POGIL follows a systematic cycle of exploration, concept invention, and application. However, POGIL alone presents challenges in visualizing abstract mathematical relationships. To address this limitation, GeoGebra, a dynamic visualization tool, was integrated to help students effectively link geometric and algebraic concepts. A mixed-methods approach was employed, incorporating a quasi-experimental pre-test/post-test control group design for the quantitative phase and a descriptive case study for the qualitative phase. The study involved 149 Grade 10 students from three public secondary schools in Addis Ababa, Ethiopia, divided into three instructional groups: (1) GGS-POGIL, (2) POGIL-only, and (3) conventional instruction. Quantitative data were collected using the Mathematical Connection Skills Test (MCST), administered before and after the intervention. Qualitative data were gathered through 12 classroom observations and semi-structured interviews with six students to capture in-depth insights into students' experiences and learning processes. Findings indicate that GGS-POGIL significantly enhanced students' intra-mathematical connections, particularly in logical reasoning, part-whole relationships, and linking multiple representations, leading to a shift from procedural to conceptual understanding. Qualitative results further revealed that GeoGebra's interactive features enabled students to grasp centroid properties and geometric transformations more effectively than traditional methods. While the POGIL-only group showed moderate improvement through structured inquiry, the conventional instruction group demonstrated minimal progress, reinforcing the limitations of passive learning. These findings highlight the transformative potential of integrating technology into structured inquiry-based learning frameworks to strengthen mathematical connections in geometry education.

Keywords: GeoGebra, Process-Oriented Guided Inquiry Learning, Mathematical Connection Skills, Geometry Learning, Mixed-Methods Research.

P02-2: The Development of Contextual Problem-Based Learning Intervention to Enhance Students Higher-Order Thinking Skills in the Teaching-Learning of Secondary School Mathematics

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Abstract

The study, part of a doctoral dissertation, aims to create a higher-order thinking skills (HOTS)-oriented instructional intervention using the contextual problem-based learning model to improve secondary school mathematics teaching and learning. The study utilized a development research model with three iterative cycles of design and redesign, involving two PhD supervisors, five experts, and a field trial with 20 grade 11 students in Jimma City. The development of the C-PBL intervention was based on literature review, empirical evidence, and qualitative textbook analysis. Data was collected through mixed methods questionnaires, analyzed using descriptive statistics, and qualitative data combined narratively. The C-PBL intervention was validated by experts for its theoretical validity, practicality, clarity of objectives, language precision, coherence, quality of problems and activities, and instructional strategies and assessment mechanisms, with high agreement. The C-PBL intervention was assessed by students in a field trial for its efficacy, inclusion of HOTS-based problems and activities, engagement, clarity of instructions, and support mechanisms, indicating agreement with the intervention. The model was restructured to include real-life context problem-solving. The final refined prototype, consisting of eight lessons and one independent problem-solving project, showed good potential quality for implementation. The study demonstrated how HOTS-based practices be designed, developed and implemented in a particular context to enhance students HOTS in the teaching-learning of secondary school mathematics, hence adding new knowledge and widening the scope for further study. Furthermore, the C-PBL lessons developed and improved during subsequent trials could serve as exemplar to help teachers prepare HOTS-based contextual problems in school mathematics, guided by the C-PBL principles.

Keywords: higher-order thinking skills, contextual problem-based learning, HOTS based instruction, problem- solving, development research

P02-3: Learning Trajectories in Ethiopian Secondary School Mathematics Spiral Curriculum Materials

Yenealem Ayalew[1*], Solomon Areaya[2] and Solomon Abedom[3]

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Abstract

The development, reform, content, and use of textbooks have always been pivotal in mathematics education research. The current grade 1 through 12 mathematics curriculum in Ethiopia was developed through a tripartite collaboration involving: (i) the Ministry of Education and Bahir Dar University (BDU); (ii) a pool of professionals from Addis Ababa University, BDU, Jimma University, and Hawassa University; and (iii) consultants from Elixir Research and Consultancy PLC, Cambridge Assessment, and the JICA-MUST project. The spiraling of the contents and cross-curricular links are well considered in the curriculum development. Theoretically, a spiral curriculum involves organizing key concepts and skills at increasing levels of complexity over time. From this perspective, the mathematics curriculum can be seen through its components: Flow Chart, Minimum Learning Competencies, and Syllabus, which serve as foundations for the writing of students' textbooks and teachers' guides. How effectively can they serve as a term of reference (ToR)? The syllabus designates the number system as the first unit of Grade 9 mathematics. However, the textbook begins with "further on set" before the number system. Additionally, the Grade 10 mathematics textbook includes two more sub-units: “solving exponential and logarithmic equations” and “equation of a circle.” On the other hand, the syllabus treats “vectors and transformation of the plane” as one unit in Grade 11, whereas the corresponding textbook addresses “vectors” and “transformation of the plane” separately and in detail. Moreover, the Grade 12 mathematics syllabus considers "pre-calculus" without formally introducing the concept of "limit," while the textbook has replaced it by "calculus”. The critical question arises: Why do such changes appear in textbooks after the syllabus is approved as a ToR? Our aim is not to audit textbooks against the ToR but to reflect on these discrepancies. We pose several questions, focusing primarily on two: Is it not possible to teach the number system without first addressing the set? Is it feasible to introduce the derivative without the concept of limits? We argue for and against the positions taken in secondary school mathematics textbooks, supported by a theoretical framework of spiral curriculum design based on the syllabus-textbook alignment. To this end, we have reviewed international experiences and textbook research practices. As a result, we address pertinent instructional methods for the sampled topics. This manuscript aims to contribute to mathematics textbook research and development.

Key Terms: mathematics, prior knowledge, spiral curriculum, textbook research

P02-4: Analytic Elliptic Operators of Any Order

Prof. Shif Berhanu[1]

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Abstract

In the early nineties, X. Huang and Krantz, and independently, M.S. Baouendi and Linda Rothschild, proved the following boundary unique continuation result for harmonic functions: Let B^+ be a half-ball in the upper half-space in $\mathbb{R}^n$, with u continuous on B^+, harmonic in B^+, and $u(x', 0) \geq 0$ for x' in a neighborhood of the origin on the flat piece of ∂B^+.

If u vanishes to infinite order at the origin in the sense that:

$$u(x) = O(|x|^N) \text{ for all } N, \text{ then } u \equiv 0.$$

Baouendi and Rothschild conjectured that a similar result holds for more general domains and general second-order elliptic operators with real analytic coefficients. We will discuss our positive solution of the conjecture and an extension to elliptic differential operators of any order. Our results have applications to several complex variables, which was the original inspiration for the four authors.
(Work supported in part by NSF DMS 1855737, NSF DMS 2152487)

P02-5: On the Gaps of Numerical Semigroups Generated by two Consecutive Odd Natural Numbers

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Abstract

We investigate the relationship between consecutive odd natural numbers and their Least Common Multiple (LCM). We explore the structure of numerical semigroups generated by consecutive odd natural numbers and examine the gaps that arise within these semigroups. Through integer modulo-n, we establish key relationships between the LCM and GCD of two consecutive odd natural numbers and explore how these properties influence the distribution of gaps. Various examples are provided to support the findings.

Keywords: Numerical semigroup, Gaps, Frobenius number, Least common multiple, Greatest common divisor.

P03-1: Solar Radiation Application with Unsteady Ternary Hybrid Nanofluid Flow in Darcy-Forchheimer Past a Stretching Surface under Non-Fourier Heat Flux

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Abstract

In the modern world, solar energy is increasingly utilized as a primary source of heat in various technologies, such as photovoltaic cells, solar panels, water pumping systems, photovoltaic lighting, and more. The integration of nanotechnology with sun-based thermal radiation has emerged as an innovative approach to enhance the thermal efficiency of solar energy. This study investigates the competence of ternary hybrid tangent hyperbolic nanofluid flow over a Darcy-Forchheimer porous stretching surface using a parabolic trough solar collector (PTSC) to improve the thermal efficiency of solar-powered aircraft. The working fluid consists of a mixture of copper (Cu), iron oxide (Fe3O4), and silica (SiO2) nanoparticles dispersed in ethylene glycol (EG), modeled as the fluid flow inside the PTSC-equipped solar aircraft wings. The thermal energy characteristics are analyzed under the influence of the Cattaneo-Christov heat flux model and quadratic thermal radiation, combined with convective heating. Additionally, entropy generation is examined for the ternary hybrid nanofluid, and the effects of variable viscosity, velocity slip, magnetic field, buoyancy force, porous media, viscous dissipation, and heat generation are incorporated in the present study. The governing coupled partial differential equations (PDEs) are transformed into non-dimensional ordinary differential equations (ODEs) using appropriate similarity transformations and solved numerically by a well-known finite difference approach named the Keller-box method (KBM). The influence of control parameters on the velocity profile, shear stress, temperature distribution, drag coefficient, Nusselt number, and entropy generation is analyzed through graphical and tabular representations. The finding highlights an improvement of solar aircraft wings in relation to heat transfer for intensified thermal radiation, magnetic field, viscous variant and thermal conduction, while reduced for viscous dissipation and thermal relaxation time. Also, the Weissenberg and Forchheimer constants lower velocity curves because of improved fluid resistance force and relaxation time. Further, ternary hybrid nanofluids demonstrate superior thermal transfer capabilities compared to hybrid nanofluids. The present study outcome reveals good congruence with the relevant literature.

Keywords: Darcy-Forchheimer, Solar radiation, unsteady flow, ternary hybrid nanofluid, non-Fourier heat flux, stretching surface.

P03-2: Impact of Permeability and Inclined Magnetic Field on Two Immiscible Newtonian and Couple Stress Fluids Flow through a Porous Pipe

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Abstract

The objective of the present article is to study the flow behavior of two immiscible couple stress and Newtonian fluids through two concentric cylinders filled with porous media having porous space of different permeability subjected to an inclined magnetic field. The entire flow regime basically consists of two separate porous regions having different specific permeabilities, in which the flow of couple stress fluid takes place in core region while Newtonian fluid in the annular region of concentric cylinders respectively. The fluid motion is generated due to a constant pressure gradient applied to the flow direction, in the presence of an inclined magnetic field. The governing equations for the two-fluid flow situation are formulated mathematically using the Brinkman equations adapted for porous media, while the influence of the inclined magnetic field is accounted for by introducing the Lorentz force into the momentum equations. The modeled equations are cast into a dimensionless form and then solved analytically by using well-known and appropriate boundary conditions which are no-slip condition (zero velocity on the stationary surface of the cylinder), continuity conditions (no mass transfer at the interface) and vanishing of couple stress at the interface of two fluids using no spin condition. Exact expressions for the velocity field, the total flow rate, and stresses are obtained in terms of modified Bessel functions. The significant effects of permeability parameter, magnetic field, angle of the inclined magnetic field, and different flow parameters like couple stress fluid parameter, viscosity ratio and pressure gradient on the velocity profile, flow rate and wall shear stress are investigated and discussed in detail. The graphical analysis and tabular data are presented to illustrate the effect of pertinent fluid flow parameters. Preliminary results indicate that variable permeabilities of the two porous regions significantly influences the flow rates of both immiscible Newtonian and couple stress fluids. In addition, the presence of an inclined magnetic field alters the flow structure, with varying impacts depending on the angle of inclination. Therefore, the findings suggest that the different specific permeabilities of the two porous regions and magnetic field orientation plays a critical role in determining the flow characteristics of immiscible fluids and must be carefully considered when designing systems that utilize porous pipes for fluid transport. The model has also a practical significance and is applicable for the process of extraction of crude oil through the porous pipes, blood flow through arteries, study of biofluids such as blood, and filtration process etc. The study is novel as it examines, for the first time, the effects of different permeabilities and an inclined magnetic field on the flow of two immiscible fluids (couple stress and Newtonian) through a porous pipe.

Keywords: Permeability, Inclined Magnetic Field, Immiscible Fluids, Newtonian Fluid, Couple Stress Fluid, Porous medium, Exact solutions.

P03-3: Impact of Variable Transport Properties on Unsteady Williams on Nano fluid Flow over a Rotating Cone under Radiative and Chemically Reactive Conditions

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Abstract

The investigation of fluid flow in chemically reactive and thermally radiative rotating systems is pivotal for applications such as drilling operations, rotating machinery, biomedical engineering, geothermal energy, and rotary filters. These applications demand optimized heat and mass transfer, with nanofluids offering a promising approach to enhance thermal and flow performance. This study examines the effects of variable thermophysical properties on the unsteady flow of Williamson nanofluids over a vertically rotating cone, incorporating chemical reactions and thermal radiation. A self-similarity transformation reduces the governing PDEs to ODEs, considering inverse linear variations of the cone's angular velocity and free stream angular velocity over time. The spectral relaxation method is employed for numerical solutions under prescribed wall temperature and concentration (PWTC) and prescribed heat and mass flux (PHMF) conditions. Findings indicate that tangential and azimuthal momentum respond inversely to parameter variations. Variable thermal conductivity and solutal diffusivity augment temperature and concentration fields in the PWTC scenario but attenuate them in the PHMF case. A combined increase in variable viscosity and suction/injection parameters enhances the tangential skin friction coefficient by 26:22% and the azimuthal coefficient by 139:68%. The Nusselt number rises by 58:34% with simultaneous increases in variable thermal conductivity and linear radiation parameters, and by 81:10% when nonlinear radiation parameters are considered instead. Additionally, chemical reaction rates olster mass transfer, whereas elevated variable diffusivity mitigates it.

P03-4: Boundary-Domain Integral Equations to Mixed BVP for Variable-Coefficient Helmholtz Equation in 2D

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Abstract

In this talk, we formulate boundary-domain integral equations (BDIEs) to the mixed boundary value problem (BVP) for variable-coefficient Helmholtz equation in two-dimensional bounded domain. Using appropriate parametrix, this problem is reduced to four systems of BDIEs. It is shown that the BVP and the formulated BDIE systems are equivalent. Fredholm properties and unique solvability and invertibility of BDIE systems are investigated in appropriate Sobolev spaces.

P03-5: Recursive Polynomials: Theory and Applications

Prof. Aklilu Zeleke

Abstract

Recursive polynomials arise naturally in many areas of mathematics and computer science, from combinatorics and differential equations, to coding theory and cryptography. In this talk, we will focus on Fibonacci-like recursive polynomials defined by second-order linear recurrence relations, such as $P_n(x) = a(x)P_{n-1}(x) + b(x)P_{n-2}(x),\ n \geq 2,\ P_0 = \alpha,\ P_1 = \beta$. Here $a(x)$ and $b(x)$ are some functions of x and α, β are real numbers. We will discuss algebraic, combinatorial and analytic properties unique to these polynomials. If time permits, we will present their connections to matrix recurrences, and generalizations to multivariate recursive polynomials.

Panel 04: Applied Mathematics

P04-1: Mathematical Model Analysis of Leptospirosis Transmission Dynamics within Cattle and Rat

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Abstract

Leptospirosis is a global zoonosis that is most prevalent in tropical or sub-tropical countries and threatens livestock productivity. In order to examine the role of rats in leptospirosis transmission dynamics, this work aims to develop and analyze a mathematical model that takes into account the direct contact within cattle and with rats as well as the indirect transmission via the free-living *Leptospira* in the environment. For the proposed model, fundamental characteristics of the model solution are examined, along with the equilibria points and their stability analysis. Additionally, we used the next-generation matrix technique to get the model's basic reproduction number, $R0$. The stability analysis revealed that the *Leptospira*-free equilibrium point is locally and globally asymptotically stable if $R0 < 1$ and unstable otherwise. The normalized forward sensitivity index is also used to determine which parameters have the most impact on the model. The stability behavior of *Leptospira*-persistent equilibrium and *Leptospira*-free equilibrium points are further demonstrated numerically. Moreover, the most sensitive parameters on the stated model are identified as the transmission rate within cattle, the transmission rate from rat to cattle, and the death rate of rats. According to our findings, lowering the rates of transmission, accelerating the rate of recovery, and reducing the rat population through the use of suitable interventions significantly contribute to limiting the spread of disease. Finally, simulation of the model is demonstrated, exploiting the odeint package from the Python library.

Keywords: Mathematical model, leptospirosis, basic reproduction number, numerical simulation.

P04-2: Analysis of Hopf Bifurcations in Delayed Predator-Prey Models with Prey Refuges

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Abstract

This paper explores the dynamics of a time-delayed predator-prey system with a prey-refuge functional response. The model integrates two critical time delays: the prey's life cycle transition time and the predator's reaction time during prey interactions. Analytical investigations focus on the system's stability and the conditions for Hopf bifurcations at the positive equilibrium. The study demonstrates that delays can destabilize the system and induce periodic behavior. We derive the properties of bifurcating periodic solutions, such as stability and period, using the center manifold theorem and normal form theory. Numerical simulations validate the theoretical results, revealing that supercritical Hopf bifurcations yield asymptotically stable periodic solutions and subcritical bifurcations yield orbitally asymptotically unstable solutions. These findings provide valuable insights into the complex dynamics of predator-prey interactions influenced by time delays and refuge-based functional responses.

Keywords: Predator-Prey Model, Refuges, Time Delay, Hopf bifurcation, Stability, Functional response.

P04-3: Adapted mesh for singularly perturbed time-fractional parabolic reaction-diffusion equations

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Abstract

In this study an adapted singularly perturbed one-dimensional time-fractional parabolic reaction-diffusion problem is presented. Using the implicit Euler technique, the time fractional derivative is handled by the Caputo fractional sense. In order to discretize the space direction an exponential B-spline collocation technique on a Shishkin mesh is implemented. The convergence of the scheme is verified, and has an accuracy of $O(N-2(lnN)2+(\Delta t)2-\alpha)$. To test the effectiveness of the scheme three model examples are considered. The results generated through tables and fgures for various values of α and ε support the theoretical predictions. The scheme is uniformly convergent and has dual layers at the end of space domain.

Nomenclature:

$\varepsilon =$ Perturbation parameter
$\alpha =$ Order of fractional derivative

P04-4: Mathematical Modeling and Analysis of Malaria Transmission dynamics Under Temperature Variability and Optimal Control Analysis

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Abstract

Malaria has not been completely eradicated, and it continues to be a major cause of high infectious illness mortality. New vaccines and therapies are constantly being developed. This study explores the impact of temperature fluctuations on malaria transmission dynamics using an age-structured, non-linear deterministic mathematical model. The model incorporates the mosquito's aquatic stages eggs, larvae, and pupae in a separate compartment. The analysis ensures the non-negativity and boundedness of the solutions. Stability analysis reveals that the disease- free equilibrium is both locally and globally asymptotically stable when fundamental reproduction number is less than one. A sensitivity analysis is performed to evaluate the parameters influencing the basic reproduction number. The model incorporates temperature-dependent factors, demonstrating that variations in temperature have a substantial impact on malaria transmission dynamics. The study finds that at the optimal temperature of 25°C, mosquito size, biting frequency, and case counts all increase. It is shown that the aquatic stages of mosquitoes, within the temperature range of 20°C to 25°C, play a critical role in malaria dynamics. The model also incorporates time-dependent control strategies, including indoor residual spraying, symptomatic treatment, screening and treatment of asymptomatic carriers, and the use of long-lasting insecticidal nets. Using Pontryagin's Maximum Principle, the study evaluates the optimal strategies for controlling the disease. Numerical simulations of the optimal control problem indicate that the most effective approach to reducing infection rates is the combined application of all four control measures. Using the numerical method of ode45, we performed integer-order simulations in MATLAB.

Keywords: Dynamics of malaria; age structure; symptomatic and asymptomatic individual; temperature; optimal control.

P04-5: Assessing the Impact of Migration on Corruption Dynamics

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Abstract

Migration of population plays an important role in the geographical spread of corruption at different levels of predominance. In this work, we have proposed a two-patch mathematical model in order to examine the effect of population migration on corruption dynamics with different levels of prevalence between patches. Using the next-generation matrix technique, the basic reproduction number R_0 at corruption-free equilibrium was computed.Analysis of the model reveals that it has exactly four equilibriums, namely, corruption-free equilibrium, two boundary-endemic equilibrium, and endemic equilibrium. The stability analysis results indicate that when the $R_0 < 1$, the corruption-free equilibrium points are asymptotically stable both locally and globally, whereas the endemic equilibrium points are asymptotically stable locally when the $R_0 > 1$. In addition, the model's parameter sensitivity was examined. Numerical simulations indicate that people migration can help the corruption to become endemic in both patches, even though the corruption can decline out in each isolated patch. However, if migration rates are continuously increased, the corruption may endemic again in both patches.

Keywords: Corruption, two-patch model, basic reproduction number, stability analysis, numerical simulation.

P04-6: A Newform theory for mod-p Katz Modular Forms

Prof. Daniel Berhanu

Abstract

In this presentation, we will provide a definition of mod-p Katz newforms. Then strong multiplicity-one theorems for mod-p Katz modular forms are proved. We show that acuspidal mod-p Katz eigenform which admits an irreducible Galois representation is in the level and weight-old space of a uniquely associated mod-p Katz newform. Time permitting, we will also set up variants of multiplicity-one results for mod-p Katz eigenforms which have reducible Galois representation.

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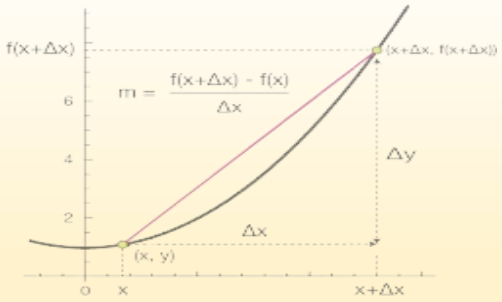
$$(x^2 + y^2 - 1)^3 - x^2y^3 = 0$$



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