The 31st USA/USM/SELU Research Mini-Conference
Friday, April 12, 2024
School of Mathematics and Natural Science
The University of Southern Mississippi
Hattiesburg, MS 39402
https://www.usm.edu/mathematics-natural-sciences/mini-conference.php

Time	Location: Hub Room G in the Thad Cochran Center Building
9:00	Welcome remarks by Dr. Theo group photo
9:20	Faculty and student presentation 9:20: Dr. James Cho (SELU) 10:00 Anzhelika Vasilyeva (USM)
10:15	Coffee Break
10:30	Student Presentations (3) 10:30: Cassie Owens (SELU) 10:45: Cassie Owens and Kara Barbier (SELU) 11:00: Abel Gurung (USM)
11:15	Coffee Break
11:30	Student Presentations (2) 11:30: Courtney Francois (USM) 11:45: Noah Frost (USA)
12:00-1:30 pm	Lunch break (Lunch is provided)
1:30	Student presentations (3) 1:30: Franissa Simon (USM) 1:45: Luke Fontan (USM) 2:00: Rebecca Scariano (USM)
2:15	Coffee Break
2:30	Student Presentations (3) 2:30: John Clark (USA) 2:45: Morgan Wilson (USM) 3:00: Jacob Gardner (USM)
3:15-	Coffee Break
3:30	Student presentations (2) 3:30: Christopher Anderson (SELU) 3:45: Manitejus Kotikalapudi (USM)
4:00	Closing Remark by Dr. Schroeder Conference ends

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Abstracts

Title: Optical interferometric study of the mechanisms of fatigue fracture

Authors: Christopher Anderson, Yuki Abe, Tomohiro Sasaki, Sanichiro Yoshida (speaker: Christopher Anderson, Southeastern Louisiana University)

Abstract: This study explores the physical mechanism of fatigue fracture using electronic speckle pattern interferometry (ESPI) and a wave theory of deformation and fracture. ESPI forms the contours of differential displacement of solid objects under deformation at each time step as optical interferometric fringe patterns. The wave theory indicates that the initiation of total fracture is similar to the transition from glow to arc discharge in gas media. In a gas discharge, both displacement current (energy conservative) and conduction current (energy dissipative) can carry the electromagnetic energy between the electrodes. In the transition to arc discharge, charges accumulate which increases the conductance, which causes more charges to accumulate until the conduction current becomes the dominant energy carrier. In our case of fatigue fracture, minor plastic deformation during a cycle causes a rotation in the material to occur. This rotation creates a shear force which leads to more plastic deformation, creating a positive feedback loop until the material breaks, indicating that a specific fringe pattern is analogous to a conduction current.

Title: The Potential of Protein-Induced Metal Nanomaterials in Medicine

Presenter: James Cho (Southeastern Louisiana University)

Abstract: In recent years, protein-induced metal nanoparticles have gathered attention in the medical field due to their outstanding attributes, such as biocompatibility, targeting ability, stability, and tunable properties. These nanoparticles, synthesized through controlled methods utilizing proteins as reducing and capping/stabilizing agents, enable precise adjustments of size, shape, and surface characteristics. This facilitates targeted and selective drug delivery, tissue imaging, and therapeutic approaches in the treatment of cancer, infectious diseases, and other medical conditions.

Title: THE SEARCH FOR SLOW PARTICLES AND MAGNETIC MONOPOLES WITH NOVA

Presenter: John Clark (University of South Alabama)

Abstract: Singular magnetic poles, north or south, have been formally theorized to exist since Dirac's paper on them in 1931. This elusive singular magnetic monopole still eludes us. The appearance of this particle would help confirm many GUT theories and revolutionize our understanding of some of the fundamental forces of the universe. Fermilab's NOvA team has a subgroup working on ways to screen and detect magnetic monopoles coming from outer space using NoVA's neutrino detector. In this talk, discussion will be focused on what NOvA is, what

magnetic monopoles are, how its detector can be used to spot magnetic monopoles, and the contributions I have made to the research.

Title: A Family of Integrals of Legenedre Polynomials
Presenter: Luke Fontan (The University of Southern Mississippi)
Abstract: This research examines particular solutions to integrals of Legendre Polynomials in order to generalize a solution for different cases of the integral of a product of a power function and two Legendre Polynomials over a set interval. We observe solutions to specific cases of degrees, generalize these cases in terms of a constant variable, and find a recurrence for the integral using recurrence-finding algorithms that we solve to verify its equivalence to our generalized solution. Our work finds an interesting way to prove generalized solutions of Legendre Polynomials and several new solutions.

Title: Sound Waves: A Mathematical Exploration of Music through Fourier Signal Analysis
Presenter: Courtney Francois (The University of Southern Mississippi)
Abstract: Music is often only expressed in the form of composing or analyzing the music through the eyes of music theorists. However, mathematicians can express music through the sinusoidal waves it creates. This paper seeks to explore the mathematical connection to music by employing Fourier transformations for the analysis of sound signals. The subjects used to complete the research include sinusoidal functions of various frequencies and orthogonal functions that are solutions of differential equations to approximate and recover sound signals. In addition, MATLAB is necessary to graph the functions and transformations.

Title: Synthesis of Ultrathin ZnO Using Physical Vapor Deposition Method
Presenter: Noah Frost (presenter), Theodore Cramer, and Arjun Dahal (University of South Alabama)
Abstract: Ultrathin zinc oxide (ZnO) is a promising material for potential photocatalysis applications, such as producing green hydrogen by splitting water in the presence of sunlight. Synthesizing high-quality ultrathin ZnO is a fundamentally important step in realizing their applications. The physical vapor deposition (PVD) method is a promising method for preparing ultrathin ZnO because it allows tuning the amount of material deposited on a substrate so that ultrathin ZnO with atomic level thickness can be fabricated. Here, we investigated the utilization of a semi-sealed quartz tube to enhance the partial pressure of ZnO, thereby optimizing its growth. We utilized Al_2O_3 as a substrate to synthesize ZnO using the PVD method. Our study shows that employing a semi-sealed quartz tube facilitates the growth of enlarged, crystalline ultrathin ZnO compared to the absence of the tube. The atomic force microscopy measurements reveal that these ultrathin ZnO islands exhibit a thickness as low as ~ 1 nm while their lateral size extends up to ~ 6 nm. As more Zn atoms are exposed to the ultrathin ZnO surfaces that provide many active sites for catalytic reactions, these ultrathin ZnO can potentially be useful for photocatalytic applications.

Title: Differential Equation Modeling the Covid-19 Pandemic with Analysis on Parameter Changes by Theoretical Vaccine Introductions in Mississippi
Presenter: Jacob Gardner (The University of Southern Mississippi)
Aabstract: We made a SEIRD model according to behaviors of the COVID-19 pandemic. This model will divide the population into susceptible, exposed, infected, removed, and deceased groups. We found the reproduction number and performed a stability analysis. We then made a

MATLAB program to incorporate CDC data on COVID-19 for Mississippi to create prediction curves. We then introduced a vaccine at different stages of the pandemic to see how the curves' parameters changed.

Title: Modeling the Open Probability of Ion Channels using Deep Neural Networks
Presenter: Abel Gurung (The University of Southern Mississippi)
Abstract: Many biological processes are modeled using differential equations. However, determining the underlying equations analytically becomes highly challenging due to the complexity and unknown factors inherent in these biological processes. Our research aims to employ deep neural networks (DNNs) to model the open probability of ion channels, a task that can prove to be intricate when tackled with ordinary differential equations (ODEs). The distinctive contribution of this research lies in reducing the number of unknowns required to model the open probability. When trained with valid data, the same neural network architecture can be employed for different ion channels, such as sodium, potassium, and calcium. Further, based on the given data, we can build a more physiologically reasonable DNN model that can be customized. Numerical results are provided to demonstrate the flexibility and effectiveness of the DNN model.

Title: Abelian Sandpile Encryption
Presenter: Manitejus Kotikalapudi (The University of Southern Mississippi)
Abstract: The Abelian Sandpile (ASB) Model is a cellular automaton that operates on arbitrary connected graphs. Quickly after its introduction in 1987 by Bak, Tang, and Wisenfeld (BTW), it became the de facto introductory tool for the study of self-organized criticality (SOC). SOC behavior is a fundamental facet of complexity theory, and its effects can be seen in many real-life situations, from the firing of brain cells to the distribution of earthquake magnitudes. This research aims to study the viability of harnessing the ASB model for applications in cryptography. Using ASB's inherent SOC, a shared-key cryptographical system can be made that encodes and decodes data with security at least as good as comparable methods. An implementation of this shared key system was first created in pure Python; then, it was refactored into Numba-Cuda code for acceleration on a GPU. After an analysis of the time and space complexity of the model, its efficacy was compared with a current, leading shared-key technology - the Advanced Encryption Standard (AES). Further research into the ASB model might lead to the implementation of a more versatile public-private key encryption system.

Title: Silver nanoparticles synthesis using bovine serum albumin
Authors: Cassie Owens, Kara Barbier, Sanichiro Yoshida, and James Cho (speaker: Cassie Owens, Southeastern Louisiana University)
Abstract: Silver nanoparticles (AgNPs) can be synthesized using silver ions along with protein and used as an antibacterial agent. Our previous research indicates AgNPs synthesized with BSA (bovine serum albumin), a type of protein, improves the cytotoxicity against certain types of bacteria when exposed to UV light. One of our goals of the present research is to find the optimal UV exposure for the AgNPs that inhibit the growth of target bacteria and delve into the structural changes the BSA undergoes to better understand how this affects cytotoxicity. This presentation delves into the background information of nanoparticle formation and the procedure leading up to results that were exhibited during inhibition testing. Effects of cytotoxicity may be the result of structural changes in BSA at the secondary structure of the protein indicated in the Fourier-transform infrared spectra.

Title: Ultraviolet and infrared spectral analyses of Ultraviolet light-treated silver nanoparticles

Authors: Cassie Owens, Kara Barbier, Sanichiro Yoshida, and James Cho (speakers: Cassie Owens and Kara Barbier, Southeastern Louisiana University)

Abstract: In our BSA (bovine serum albumin) based silver nanoparticle (AgNP) research, the Fourier-transform IR (infrared) spectra indicate the effect of UV (Ultraviolet) exposure on the bacterial cytotoxicity results from structural changes in BSA at the secondary structure. On the other hand, the UV-Vis spectra indicate the UV absorption by BSA causes π-to-π* and n-to-π*transitions. These observations lead to our hypothesis that the UV absorption alters the charge distribution of the BSA molecules attached to the AgNPs through photochemical reactions involving the π* excited state or other types of energy transfer mechanisms from the UV to IR region, and the resultant change in the polarization of the BSA causes selective bacterial toxicity. In this presentation, we discuss our hypothesis based on spectroscopic analyses including the absorption band assignment and changes in the peak absorption with UV exposure.

Title: How to Explain Allen-Manandhar's Method to Beginner Mathematicians : a Convergence Analysis of a Hybrid Method for Variable-Coefficient Boundary Value Problems

Presenter: Rebecca Scariano (The University of Southern Mississippi)

Abstract: In short, Allen-Manandhar's method is used to solve an equation, an ordinary differential equation (ODE). Without any prior knowledge assumed, analogies in this project are incorporated to make complex math concepts approachable to beginners. Thus, the mentioned equation with its coefficients is compared to a recipe with ingredients. If the outcome to a recipe is seen as its solution then the solution to our pie recipe is a perfectly baked pie. The chosen method for baking a pie is classified as its baking approach that is executed to "solve" the recipe. However, with more complicated ingredients (variable coefficients), the resulting pie must be approximated, which introduces error. Allen-Manandhar's method is the baking approach being analyzed for how well it finds the baked pie solution to the recipe equation and is then compared to another pie baking approach. Using this analogy and a convergence analysis, the goal is determining if our baking approach produces the most perfect pie possible. To see the inner workings of our method itself, physical steps are described to perform on a cube to help translate what mathematical steps are performed on the equation to find its solution. The results show that our method loses in accuracy and efficacy when solving linear, variable-coefficient ODEs in two-point boundary value problems. While our baking approach does not bake the best or fastest pie in comparison, it shows promise with constant coefficients in certain situations, which is next to analyze.

Title: The Numerical Method for Finding All the Zeros of a Function f(x) on an Interval [a,b]

Presenter: Franissa Simon (The University of Southern Mississippi)

Abstract: Interval computation is a mathematical method for approximating values of a function f(x) on an interval [a,b]. Existing classical numerical methods, including the Bisection Method, Secant Method, and Newton Method etc., cannot find all the zeros of a function f(x) on an interval [a, b]. Popular numerical root solvers like Matlab's 'fzero', Maple's 'fsolve', and SageMath's 'find_root' typically yield only a single zero. The objective of this research is to address this limitation by developing a new numerical method for finding all the zeros of a function f(x) within the specified closed interval [a,b]. The proposed Interval Bisection Method combines a modified bisection approach and interval computation to accurately determine all the roots within a defined convergence tolerance. The future project is to further modify the current proposed method to

include the Krawczyk operator which investigates the existence and uniqueness of the root values. Another possible direction of research includes extending the current method to find all the solutions of an n-dimensional nonlinear system f(x)=0 where x in ([a,b])^n.

Title: Component-wise Backward Differentiation Formulas for Stiff Systems of Ordinary Differential Equations

Presenter: Anzhelika Vasilyeva (The University of Southern Mississippi)

Abstract: This paper offers a novel approach to computing coefficients of Backward Differentiation Formulas (BDFs) which are applied to a system of stiff ordinary differential equations (ODEs) produced by spatially discretizing a given partial differential equation (PDE).
In the new approach, each Fourier coefficient of the solution is computed using frequency-dependent coefficients for BDFs. Computational experiments revealed that Component-wise BDFs produce solutions with higher accuracy for step (m) cases m=1, 2, 3. Additionally, Component-wise BDFs were found to have a growing region of absolute stability corresponding to higher-frequency components.

Title: Knighted Pawn Tour

Presenter: Morgan Wilson (The University of Southern Mississippi)

Abstract: The Knighted Pawn Tour is a variant of the traditional Knight's Tour problem, which itself is an instance of the Hamiltonian cycle problem. The deviation from the Knight's Tour problem is that a pawn begins in any space on the second row, and advances with legal moves that can include captures to the opposite end to become a knight. These squares, used by the pawn to attain knighthood, are subsequently forbidden for the knight's return to the starting field. The knight must traverse the rest of the chessboard, visiting each square exactly once before returning to the pawn's original starting position, thus completing a Hamiltonian cycle. We are interested in which advance paths for the pawn allow for the completion of a Knighted Pawn Tour

	Participants (Affiliation)
1	Christopher Anderson (Southeastern Louisiana University)
2	Kara Barbier (Southeastern Louisiana University)
3	C.S. Chen (The University of Southern Mississippi)
4	James Cho (Southeastern Louisiana University)
5	John Clark (University of South Alabama)
6	Luke Fontan (The University of Southern Mississippi)
7	Courtney Francois (The University of Southern Mississippi)
8	Martin Frank (University of South Alabama)
9	Noah Frost (University of South Alabama)
10	Jacob Gardner (The University of Southern Mississippi)
11	Corey Guagliardo (Frederica Academy)
12	Qingguang Guang (The University of Southern Mississippi)
13	Abel Gurung (The University of Southern Mississippi)
14	Ding Jiu (The University of Southern Mississippi)
15	Theofanis Kitsopoulos (The University of Southern Mississippi)
16	Karen Kohl (The University of Southern Mississippi)
17	Manitejus Kotikalapudi (The University of Southern Mississippi)
18	James Lambers(The University of Southern Mississippi)
19	Cassie Owens (Southeastern Louisiana University)
20	Rebecca Scariano (The University of Southern Mississippi)
21	Bernd Schroeder(The University of Southern Mississippi)
22	Franissa Simon (The University of Southern Mississippi)
23	Haiyan Tian (The University of Southern Mississippi)
24	Kearsten Turner (University of South Alabama)
25	Anzhelika Vasilyeva (The University of Southern Mississippi)
26	Anna Wan (The University of Southern Mississippi)
27	Xiaodong Wang (The University of Southern Mississippi)
28	Morgan Wilson (The University of Southern Mississippi)
29	Zhifu Xie (The University of Southern Mississippi)
30	Sanichiro Yoshida (Southeastern Louisiana University)