Pi Mu Epsilon

Pi Mu Epsilon is a national mathematics honor society with 359 chapters throughout the nation. Established in 1914, Pi Mu Epsilon is a non-secret organization whose purpose is the promotion of scholarly activity in mathematics among students in academic institutions. It seeks to do this by electing members on an honorary basis according to their proficiency in mathematics and by engaging in activities designed to provide for the mathematical and scholarly development of its members. Pi Mu Epsilon regularly engages students in scholarly activity through its *Journal* which has published student and faculty articles since 1949. Pi Mu Epsilon encourages scholarly activity in its chapters with grants to support mathematics contests and regional meetings established by the chapters and through its Lectureship program that funds Councillors to visit chapters. Since 1952, Pi Mu Epsilon has been holding its annual National Meeting with sessions for student papers in conjunction with the summer meetings of the Mathematical Association of America (MAA).

MAA Student Chapters

The MAA Student Chapters program was launched in January 1989 to encourage students to continue study in the mathematical sciences, provide opportunities to meet with other students interested in mathematics at national meetings, and provide career information in the mathematical sciences. The primary criterion for membership in an MAA Student Chapter is “interest in the mathematical sciences.” Currently there are approximately 550 Student Chapters on college and university campuses nationwide.
# Schedule of Student Activities

Unless otherwise noted, all events are held at the Monona Terrace

Please note that there are no MAA Sessions #18, or 22-26 and there are no PME Sessions #7-10.

## Wednesday, August 1

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<tr>
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<tr>
<td>2:00 pm - 4:00 pm</td>
<td>CUSAC Meeting</td>
<td>Hilton Madison Founders Room</td>
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<td>4:30 pm - 5:30 pm</td>
<td>MAA/PME Student Reception</td>
<td>Hall of Ideas G/J</td>
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<tr>
<td>5:30 pm - 6:30 pm</td>
<td>Face Off!</td>
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## Thursday, August 2

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<td>8:30 am - 11:30 am</td>
<td>PME Council Meeting</td>
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<td>MAA Session #1</td>
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<td>MAA Session #5</td>
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<td>8:30 am - 10:25 am</td>
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<td>9:00 am - 5:00 pm</td>
<td>Student Hospitality Center</td>
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<td>MAA Lecture for Students</td>
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<td>MAA Session #7</td>
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<td>8:30 am - 11:45 am</td>
<td>MAA Session #15</td>
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<td>PME Session #6</td>
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<td>9:00 am - 5:00 pm</td>
<td>Student Hospitality Center</td>
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<td>MAA Student Activities Session:</td>
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<td>1:00 pm - 1:50 pm</td>
<td>Entertaining Math</td>
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<td>MAA Session #19</td>
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<td>MAA Session #20</td>
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<td>MAA Session #21</td>
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<td>6:00 pm - 7:45 pm</td>
<td>PME Banquet and Awards Ceremony</td>
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<td>8:00 pm - 8:50 pm</td>
<td>J. Sutherland Frame Lecture</td>
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<tr>
<td>9:00 pm - 10:00 pm</td>
<td>MAA Ice Cream Social and Awards</td>
<td>Community Terrace</td>
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### Saturday, August 4

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<td>Student Hospitality Center</td>
<td>Exhibit Hall B</td>
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<tr>
<td>9:00 am - 10:30 am</td>
<td>MAA Modeling (MCM) Winners</td>
<td>Hall of Ideas F</td>
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<tr>
<td>1:00 pm - 2:15 pm</td>
<td>Student Problem Solving Competition</td>
<td>Meeting Rooms K &amp; L</td>
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</table>
We are familiar with the prime numbers as those integers that cannot be factored into smaller integers, but if we consider systems of numbers larger than the integers, the primes may indeed factor in those larger systems. We discuss various questions mathematicians ask about how primes may factor in larger systems, talk about both classical results and current research on the topic, and give a sense of the kind of tools needed to tackle these questions.
MAA Lecture for Students

GEOMETREKS

Ivars Peterson
Mathematical Association of America

Few people expect to encounter mathematics on a visit to an art gallery or even a walk down a city street (or across campus). When we explore the world around us with mathematics in mind, however, we see the many ways in which mathematics can manifest itself, in streetscapes, sculptures, paintings, architectural structures, and more. This illustrated presentation offers illuminating glimpses of mathematics, from Euclidean geometry and normal distributions to Riemann sums and Möbius strips, as seen in a variety of structures and artworks in Washington, D.C., Philadelphia, Toronto, Montreal, New Orleans, Madison, Wisconsin, and many other locales.
MAA Undergraduate Student Activities Sessions

ENTERTAINING MATH: JUGGLING, MAGIC AND CIRCUS TRICKS

Tim Chartier
Davidson College

Ballroom B

Love math but felt ever stuck on how to get someone else excited? How about juggling, presenting a magic trick, or performing a circus trick like balancing an object on your hand to teach or motivate a mathematical idea? This activity will explore ways to demonstrate and discuss mathematics using techniques generally associated with entertainment and the performing arts. Come ready to learn a few tricks and possibly some new math!

MATHEMATICAL UNTUITION - JUST HOW FAR ASTRAY CAN YOUR MATHEMATICAL COMMON SENSE MISLEAD YOU?

Brian Conrey
American Institute of Mathematics

Ballroom C

During this session we will discover some simple but truly surprising mathematical facts.
### MAA Student Speakers

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<tr>
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# Pi Mu Epsilon Speakers

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## Delegates

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Approximating a Hurricane’s Path and Position Using Simplified Weather Models
Guy B. Oldaker
North Carolina A&T State University

Every year, the coasts of the U.S. are threatened by hurricanes. On the minds of many inhabitants is: “Where will the storm strike?” In this study we will explore how a hurricane’s track can be approximated based on the observation data from NASA and apply some simple approaches to try and predict its future position. The goal of this project is to find the direct link between our daily weather phenomenon (e.g. hurricanes) and the differential equations (DEs) learned in regular classrooms. The considered models are the simplified underlying equations from the prediction models in our real weather forecasting systems. We will begin by solving, first a simple DE, and then a system of simple DEs, analytically and numerically, and comparing the results using Matlab programs. Next, we will interpolate a hurricane's path using its average velocity and compare it to the actual path. From there, we will move to two simplified weather models: one uses the observed pressure data and the other is a simple beta-advection model (BAM). Finally, we will present conclusions and some future improvements.

Mathematical Modeling the Growth and Spread of Marram Grass Populations in Vegetated Sand Dunes
Cara Cannon
Hope College

The presence or absence of plants critically affects the physical processes that shape and form vegetated sand dunes. This is due to the fact that roots impede erosion, while foliage promotes sand accumulation by slowing down the wind. Ammophila breviligulata (marram grass) thrives under conditions of moderate sand burial. This introduces interesting feedback dynamics, because the grass’ presence impacts accumulation of sand, which, in turn, stimulates plant growth and spread. In this talk we will examine one side of this interaction by mathematically modeling marram grass population dynamics in the presence of sand burial. The model incorporates both local growth and spread through the use of integrodifference equations. Through model simulations we will address important questions relating to vegetated dune dynamics including whether population dynamics alone can lead to the formation of blowout sand dunes.
9:10–9:25

Phytoplankton Analysis in the St. Lawrence River
Samantha Longdaue, Domonique Powell, and Joshua Kalar
Clarkson University

Our major goal this summer is to model phytoplankton population in the St. Lawrence River. Due to prior research, our focus has narrowed down to phytoplankton interaction with vegetation fields, which include organisms that attach to plants and feed on the phytoplankton that pass by. These organisms are called grazers, and their consumption impacts the overall rate of phytoplankton growth/decay. Our objectives are to identify which factors have significant affects on the phytoplankton population, and quantify that affect. Moreover, we want to represent the activity in the water numerically using statistical methods, such as ANOVA testing or multiple linear regression, and dynamic mathematical models. Our resources have led us to hypothesize that rotifers, benthic grazers, and water grazers all affect phytoplankton population, causing it to decrease as the interaction with vegetation increases. In other words, the plant based grazers are eating the phytoplankton in the river.

9:30–9:45

Mathematical Models for Water Scarcity
Van Ngoc Thu Pham
Southwestern University

Water shortage has become one of global problems. Social and economic damage of water scarcity is greater in urban areas than other parts in a country due to a dense population concentration and higher water demand caused by city lifestyle. Mathematical models of population, water consumption, and precipitation will be presented.

9:50–10:05

Kentucky's Potential for Woody Biomass
Amir Y. Ahmadi
Morehead State University

The search for an economically efficient alternative to petroleum-based fuel products concerns many people. In the past, food-based biofuels generated controversy due to its exorbitant usage of food product. However, second generation biofuels—more specifically, woody biofuels, overcome the controversy and have the potential to yield greater quantity of usable products. Unfortunately, this production process has yet to be fully optimized. This paper develops a numerical model for the simulation of wood pyrolysis biofuel production within a fluidized bed reactor. The results of this model are economically applied for a Kentucky wood species, Yellow Poplar, to estimate its current profitability. Conclusions shed light on short-term potential applications for the Kentucky wood market.

10:10–10:25

Recycling Toward a Better Earth Through Math
Yvette Niyomugaba
Southwestern University

As the world population increases significantly quickly, recycling is one of the effective ways to conserve and save energy and natural resources. In addition, recycling reduces landfill use and the environmental damage from pollutants and greenhouse gas emissions. Mathematical models of the production, consumption, and recycling of material will be presented.
The Mandelbrot Set and Combinatorics of Real-valued Periodic Points
Alison G. Schuetz
Hood College

We studied the combinatorics of real-valued periodic points under iterated maps

\[ f_c(z) = z^d + c. \]

For \( d = 2 \), the set of all parameters \( c \in \mathbb{C} \) for which the orbit of 0 is bounded under these maps is known as the Mandelbrot set. For \( d \geq 3 \), these sets of parameters are called the Multibrot sets. For a given value \( c \in \mathbb{C} \), the set of all \( z \in \mathbb{C} \) for which the orbit is bounded is called the Julia set \( \mathcal{J}_c \). We classify and count these real-valued periodic points for various \( d \), as well as studying the H-compositions of the Julia sets which correspond to these real values.

To locate parameters \( x \in \mathbb{C} \) which have periodic orbits, we compute the complex roots of polynomials \( f_x^n(0) \). We examine these roots, and find partial recursion formulas for coefficients of the polynomial expansion of this \( f_x^n(0) \). The polynomials generated when working with different periods of the Mandelbrot Set are each unique; however, we find patterns relating \( f_x^n(0) \) with \( f_x^{n-1}(0) \) and \( f_x^{n+1}(0) \).

Around the Mandelbrot Set in 80 Days
Robert Vaughn
Hood College

The Mandelbrot set \( \mathcal{M} \) is the subset of the complex plane corresponding to parameters \( c \in \mathbb{C} \) such that the orbit of 0 under the map \( f_c(z) = z^2 + c \) is bounded. Given a fixed parameter \( c \in \mathcal{M} \), the filled Julia set \( \mathcal{J} \) is the set of all points \( z \in \mathbb{C} \) with bounded orbits under \( f_c \). Points \( c \in \mathcal{M} \) with period \( n \) correspond, via their orbit diagrams, with H-compositions of \( n \). We give an algorithm to locate “bulbs” and “branches” in the Mandelbrot set corresponding to a fixed H-composition

\[ n = a_1 + a_2 + \ldots + a_r. \]

In addition to mapping the patterns between points in \( \mathcal{M} \) and orbital patterns in their Julia sets \( \mathcal{J} \), we extend a known combinatorial formula for counting the number of periodic points in \( \mathcal{M} \) to one counting Misiurewicz points, i.e. points with a pure pre-period \( m \) and a period \( n \).
The History of the Primality of One
Angela Reddick
University of Tennessee at Martin

It has often been asked if one is prime number, or if there was a time when most mathematicians thought one was prime. Whether or not one is a prime is simply a matter of definition, but definitions are often decided by the use of mathematics. In this paper we will explore the history of the definition of prime as applied to the number one, from the ancient Greeks to the modern times. For the Greeks the numbers (αριθµος) were multiples of the unit, and for this reason one did not fall into the category of primes (a subdivision of the numbers). This view held with few exceptions until Stevin (c. 1685) argued successfully one was a number, at which point it finally makes sense to ask if one is prime. This is followed by a period of confusion which begins to dissipate with Gauss’ Disquisitiones Arithmeticae. Thus, for most of history, one was not considered a prime, and that there was no point in time where the majority of mathematicians viewed one as prime. Finally, we discuss who was the last mathematician to consider one a prime.

Multiple Choice Versus Open Response Assessment in Calculus
Monica Lee Chalke
Bridgewater State University

The use of multiple choice questions is becoming increasingly common in recent years as an assessment tool in Calculus. The ease of grading of multiple choice questions has lead to their widespread use to assess student understanding on homework assignments via online homework systems as well as on tests. Motivated by the question of whether or not it is appropriate to use multiple choice questions on quizzes and exams in Calculus, we conducted a study to investigate the impact of multiple choice questions versus open response questions on student understanding. The goal of our study is to identify if there is a performance gap between Calculus students who were tested via multiple choice questions on quizzes and exams versus students whose exams consisted only of open response questions. We also investigate the performance of students on particular Calculus topics when assessed using these two methods.

Symmetry of the Numerical Range
Shelby Burnett and Ashley Chandler
Cal Poly San Luis Obispo

The numerical range of an $n \times n$ matrix $A$ is a convex subset of the complex plane defined by $W(A) = \{\langle Av, v \rangle : v \in \mathbb{C}^n, \|v\| = 1\}$. The numerical range is said to have $n$-fold symmetry about the origin if $z \in W(A)$ implies $e^{2\pi i}z \in W(A)$. If $A$ is a $2 \times 2$ matrix then $A$ is a possibly degenerate elliptic disk with foci at the eigenvalues of $A$. Naturally, symmetry results for this case have been fully explored. We also know that if the entries of $A$ are real (or $A$ is unitarily equivalent to a real matrix), then $W(A)$ is symmetric about the real axis. In our talk, we will discuss natural generalizations of these results to $n \times n$ matrices where $n \geq 4$. Specifically, we will focus on $n$-fold symmetry about the origin and symmetry about particular axes.
Variations of Lollipops and Their Pebbling Numbers
Emily Marie Walther
Westminster College

This talk will first focus on understanding the fundamental concepts of pebbling and the pebbling numbers of common graphs such as paths, complete graphs, and cycles will be discussed. The pebbling number of an even cycle lollipop will be determined. We will explore the pebbling number of an odd cycle lollipop and other generalizations of the even cycle.

Non-Trivial Pursuit: A Game of Cops and Robbers
Kirstyn Baker, Caitlin Graff, Anthony Graves-McCleary, Philip Thomas, and Aashish Srinivas
Alma College, Idaho State University, Vassar College, Indiana University, and Swarthmore College

Cops and Robbers is a game played on a reflexive graph by a robber and a team of cops. The cops and the robber take turns moving between adjacent vertices of the graph with the goal of the cops being to eventually occupy the same vertex as the robber, and the robber trying to avoid this result indefinitely. The cop number of a graph is defined as the fewest number of cops needed to capture the robber given intelligent play from both sides. We examine the properties of the cop number for various classes of graphs.

Pebbling on Graphs
Mark Schrecengost and Wes Galbraith
Hope College

The pebbling problem arises from a game in graph theory. Pebbles are configured on the vertices of a graph $G$, and a pebbling move consists of removing 2 pebbles from any vertex and adding 1 to an adjacent vertex. A configuration is said to be solvable if, given any starting configuration, at least one pebble can be moved to any vertex through a finite sequence of pebbling moves.

The smallest number of pebbles that guarantees solvability of any configuration on $G$ is called pebbling number of $G$. The pebbling threshold of a family of graphs is a function $g(n)$ such that any configuration with $t << g(n)$ is almost always not solvable and with $t >> g(n)$ is almost always solvable, where $t = t(n)$ is the number of pebbles and $n$ is the number of vertices of a graph. We examined the pebbling threshold of diameter two graphs and estimates for the pebbling number of graphs of fixed diameter.
9:30–9:45

**Deterministic Walks on Graphs with Choice**

Peter Barr  
*Wake Forest University*

In this talk we consider deterministic movement on graphs, integrating local information, memory and choice at nodes. The research is motivated by recent work on deterministic random walks and applications in multiagent systems. Several results regarding passing messages through grids are discussed, as well as some open questions.

9:50–10:05

**Compatible Matchings in Bipartite Graphs**

Allison Zale  
*Illinois State University*

Consider a graph $G$ whose edges are colored with $t$ colors, where the coloring is not necessarily proper. A subset of vertices $S$ in $G$ is called feasible if for each color $c$, the vertices in $S$ are saturated by a matching with edges of color $c$. The problem of devising an efficient algorithm to find the largest feasible subset $S$ is an open question for $t \geq 2$. In our research we developed a greedy algorithm for finding a feasible subset $S$ when $G$ is a bipartite graph and the number of colors is $t = 2$.

10:10–10:25

**Pebbling a New Type of Graph**

Brandon Mosley  
*Westminster College*

In this talk we will explore various pebblings of a new type of graph. We will conjecture and prove a formula for the pebbling number of the graph, and the generalize to other related graphs.
Equal Circle Packing on a Square Flat Klein Bottle
Matthew Brems and Alexander Wagner,
Franklin College and Vanderbilt University
The study of maximally dense packings of disjoint equal circles is a problem in Discrete Geometry. The optimal densities and arrangements are known for packings of small numbers of equal circles into hard boundary containers, including squares, equilateral triangles and circles. In this presentation, we will explore packings of small numbers of equal circles into a boundaryless container called a Klein bottle. Using numerous figures we will introduce all the basic concepts (including the notion of a Klein bottle, an optimal packing and the graph of a packing), illustrate some maximally dense arrangements, and outline the proofs of their optimality. This research was conducted as part of the 2012 REU program at Grand Valley State University.

Perimeter-minimizing Planar Tilings by Pentagons
Zane Karas Martin
Williams College
Hales proved that regular hexagons provide the least-perimeter way to partition the plane into unit areas. What are the best pentagons? Could mixtures of nonconvex and regular pentagons have less perimeter than convex irregular pentagons?

Tiling Space with Tetrahedra
Andrew Richard Kelly
Williams College
What is the least-perimeter way to tile space with tetrahedra?

Tiling Space with \(n\)-Hedra
Steven Waruhiu
University of Chicago
What is the least-perimeter way to tile space with \(n\)-hedra for small \(n\)?
Non-periodic Tessellations and Quasicrystals
Karleen J. Stevens
Augsburg College

This paper explores the relationship between two- and three-dimensional non-periodic tessellations. These ideas are then extended to the chemical world in relation to quasicrystals.

10:10–10:25
Isoperimetry in the Plane with Density $e^{r^a}$
Whan Ghang
Massachusetts Institute of Technology

We study the isoperimetric problem in the plane with density $e^{r^a}$. Sometimes as in the Euclidean plane the solution is a circle about the origin, sometimes not.
An Investigation of Boundary Conditions for the Yee Scheme in Complex Geometry
Phil Ammirato, Kaitlyn Eichinger, Rita Vander Stad, Alexander Michael Hegedus, and Catherine Ross
SUNY Stony Brook, University of Kentucky, William Paterson State University, Alma College, and Rose-Hulman Institute of Technology

In this paper we will explore how waves acting under Maxwell equations interact with various shapes. We use an application of Yee’s method to solve Maxwell’s equations (Kane Yee, 1966, “Numerical solution of initial boundary value problems involving Maxwell’s equations in isotropic media”, IEEE Transactions on Antennas and Propagation). Complex geometry will be addressed using an Embedded Boundary method or a Cut Cell method over a uniform grid. We plan to numerically investigate the impact of these boundary methods on the divergence free Maxwell equations. We will implement these techniques in Python using various libraries such as NumPy and MatPlotLib. We also may explore the use of GPUs in decreasing computation time.

Turing Patterns via Agent-Based Modeling
Joshua Armstrong, Joshua Fagan, Kirstin Ladas, Gavin McGrew, and Rosa Romano
University of Richmond

In a seminal 1952 paper titled “The Chemical Basis of Morphogenesis”, Alan Turing proposed that interactions between a slowly-diffusing activator coupled to a rapidly-diffusing inhibitor could produce spatial patterns in the concentrations of those substances. Traditionally, these reaction-diffusion systems have been modeled using partial differential equations (PDE).

\[
\frac{\partial a}{\partial t} = f(a, b) + D_a \frac{\partial^2 a}{\partial x^2}
\]
\[
\frac{\partial b}{\partial t} = g(a, b) + D_b \frac{\partial^2 b}{\partial x^2}
\]

Here \( f(a, b) \), \( g(a, b) \) account for interactions between the chemical species; the extra terms account for the effects of diffusion. These PDE models describe concentrations rather than individual molecules.

In the agent-based models we will use, the molecules will be the agents, and will have their own properties, properties that can determine the nature of their interactions. For example, molecules with the property “speed” may interact through collisions and their speeds will dictate whether the energy of collision is greater than the activation energy necessary for a chemical reaction to occur. Using Mathematica, we are able to explore PDE models by implementing finite differences that are Forward-in-Time-Centered-in-Space. Using NetLogo, an agent-based modeling environment, we are able to account for individual molecules. We will replicate and compare pattern formation in Mathematica with our results in NetLogo.
9:10–9:25

**Comparison of the Influence of Sub-Networks on the Global Dynamics of Three-Gene Regulatory Networks in Boolean and Continuous Frameworks**

Miranda Henderson

*Benedictine University*

We discuss the Boolean and continuous dynamics of three-gene regulatory networks. We investigate how the presence of certain sub-networks dictate the dynamics for the entire network. We determine the conditions on these sub-networks that lead to the same or different qualitative behavior of the Boolean and continuous dynamics for the entire network.

9:30–9:45

**Pivotal Quantities, Bifurcation Continuation, and Inverse Modeling of Dynamical Systems**

Karleigh Cameron and Marissa Saladin

*Central Michigan University and Aquinas College*

Often when we use a system of equations in mathematical modeling applications, we need to be able to determine unknown parameters. Conditioning has the potential to improve the identifiability of the estimation problem. Conditioning likelihoods are typically much simpler to model than the full joint distribution which may be difficult or impossible to estimate analytically. Bifurcation continuation can inform us about feature statistics of bi-stable systems. We will be using a likelihood based estimation procedure and a Monte Carlo simulation to compare bias accuracy among various estimators. In addition, we will explore how different sources of noise manifest within a dynamical model and how such noise affects uncertainty in the statistical analysis. Systems analyzed have applications to neuroscience and cognition.

9:50–10:05

**Inverse Modeling of Dynamical Systems: Multi-Dimensional Extensions of a Stochastic Switching Problem**

Erik Bates, Blake Chamberlain, and Rachel Gettinger

*Michigan State University, Susquehanna University, and Saint Vincent College*

The Buridan’s ass problem is characterized by perpetual indecision between two states, which are never attained. When this problem is formulated as a dynamical system, indecision is modeled by a discrete-state Markov process determined by the systems unknown parameters. Interest lies in estimating these parameters from a limited number of observations. In this talk, we compare estimation methods and examine how well each can be generalized to multi-dimensional extensions of this system. We also examine the robustness of these methods when noise is introduced to the system. Conditioning has the potential to improve the identifiability of these inverse problems. In addition, conditioning likelihoods are often simpler than the full joint distribution, which may be difficult or impossible to find analytically. We will quantify various feature statistics such as amplitude, average value, variance, cumulative power, and frequency. We will compare method of moments type estimators to likelihood-based Monte Carlo simulations conditioned on these feature statistics.
10:10–10:25

Some Applications of Bifurcations in Chemistry, Biology and Engineering
Caleb J. Yonker and Michael Esch

Grand Valley State University

The mathematical concept of bifurcations has widespread applications in Engineering and the applied sciences such as Chemistry and Biology. It is especially useful in predicting how dynamical systems which commonly arise in real-life applications evolve with time. In this talk, we perform an in-depth analysis of the mathematical concepts behind some common applications of bifurcations in Chemistry, Biology and Engineering. In particular, we apply analytical techniques such as linearized stability analysis of equilibrium points and geometrical techniques where such analytical techniques fail to understand why the real-life outcomes of such applications appear as they do.
Beal’s Conjecture, Lesser-known Brother of Fermat’s Last Theorem
Jakob Weisblat
Kent State University

Most people know a certain amount about Fermat’s Last Theorem \((a^n + b^n = c^n; n \in \mathbb{Z} > 2)\) and its history. However, there is another, more general, conjecture, proposed in the 20th century, that still has not been proved or disproved. Beal’s Conjecture, also known as the Tijdeman-Zagier conjecture, states that all solutions to the equation \(a^x + b^y = c^z\) \((x, y, z \in \mathbb{Z} > 2)\) have \(a\), \(b\), and \(c\) coprime. This talk will discuss a personal search for patterns in the coprime solutions, some general coprime solutions, and finally some possible proof angles and progress of research in the last 20 years.

Determining the Primality of a Given Integer is Easy
Tim Shaffer
Youngstown State University

It is well known that determining the prime factorization of a given integer can be quite computationally expensive. In fact, outside of quantum computing, the most efficient factorization algorithm known runs a little faster than in exponential time. What may not be so well-known is that polynomial time algorithms exist that can determine the primality of a given integer. In this presentation the Agrawal, Kayal, and Saxena (AKS) algorithm and the mathematics behind the method are given, along with a comparison with other techniques, such as non-deterministic tests for “probable primes”. Consideration for how this algorithm can be implemented and applied to the search for prime numbers will also be discussed.

A Constructive Proof of the Cubic Case of Kronecker-Weber
Michael Mudarri
Hood College

The Kronecker-Weber theorem, first proved at the end of the 19th century, states that any abelian extension of the rational numbers \(\mathbb{Q}\) is contained in a cyclotomic extension of \(\mathbb{Q}\). Let \(f\) be a cubic polynomial with rational coefficients whose discriminant is a perfect square in \(\mathbb{Q}\). The Kronecker-Weber theorem implies that the roots of \(f\) can be expressed as cyclotomic numbers, i.e. as \(\mathbb{Q}\)-linear combinations of roots of unity. The usual proofs of the theorem are not evidently constructive. I will discuss an algorithm for constructing a representation of the roots of \(f\) as cyclotomic numbers using the cubic formula and classical facts from the theory of cyclotomy.
9:30–9:45

**Computational Exploration of Pseudo-Arithmetic Super Sets in \( \mathbb{Z}[\sqrt{-2}] \)**

Joshua Jacobson  
*St. Olaf College*

A set \( B \subseteq \mathbb{Z}[\sqrt{-2}] \) is defined to be pseudo-arithmetic if for \( d(B) = \{x - y | x, y \in B\} \), there exists an element of \( d(B) \) that divides all other elements of \( d(B) \). A set \( A \) is defined as a pseudo-arithmetic super set if for every subset \( B \subseteq A \) with \( \text{card}(B) \geq 2 \), \( B \) is pseudo-arithmetic. This notion was introduced by Blanchard 2004, and these sets have been classified in the integers, Gaussian integers, and Eisenstein integers. Through examples, we show a variety of pseudo-arithmetic super sets in \( \mathbb{Z}[\sqrt{-2}] \). We consider bounded and maximality of these sets as well as standard extensions to these sets. We will also discuss the unit-connected pseudo-arithmetic super sets.

9:50–10:05

**Finding Minimum Step Number of Figure-Eight Knot Confined to Slabs in the Simple Cubic Lattice**

Michael Jun  
*UC Berkeley*

Knots are commonly found in DNA and proteins and provide clues for topological analysis of their structures. Key parameters to consider in such studies are the minimum number of monomers required to construct a knot and the volume confinement in which the constructions take place. We thus approach the problem by considering the minimum length (minimum step number) needed to form a knot in the simple cubic lattice confined between two parallel planes (or by a slab). The minimum step number of a trefoil in a 1-slab has been determined to be 26 by using the Minimum Step Number (MSN) Algorithm. Though a very systematic approach, the MSN Algorithm becomes very complicated and expensive when extended to larger knots. The focus of this study is creating a computer program to aid with the enumerations. With the computer assistance, we confirm that the minimum step number of a trefoil in the 1-slab is indeed 26. Furthermore, the goal is to generalize this to the figure-eight knot, hoping to put a definite number on the minimum step number of the figure-eight knot.
Anagrams, Markov’s and Knots
Liliana Alvarez
Austin Peay State University

Our research objective is to observe the interplay of words created from scrambled letters in relation to Markov chains. Thereafter, we will study the words with regards to different types of knots. We applied stochastic modeling to anagrams that formed Markov chains. We used graph theory as an instrument to see the linkage between the world of literature and knot theory.

Vertex Polygons
Candice Nielsen
Elmhurst College

We identify necessary conditions for equal-area hexagons to have vertex quadrilaterals with equal area, discover a method for creating a hexagon whose vertex quadrilaterals have equal area without being equal-area, and generalize to construct any polygon with an even number of sides to have certain vertex polygons with equal area.

4-moveReducibilityofCables of (2p + 1, 2) Torus Knots
Andrew Tew
University of Nebraska at Omaha

In 1979, Y. Nakanishi conjectured that the 4-move operation is an un-knotting move. This conjecture is assumed to be false, even though no counterexample has been found and every knot with 12 or fewer crossings has been verified as being 4-move reducible to the unknot. It was believed for sometime that the 2-cable of the trefoil knot was a potential counter-example to the 4-move conjecture. However, in his paper “A Note on 4-Equivalence”, Nikolaos A. Askitas presented a sequence of 4-move (along with ambient isotopies) that reduced the 2-cable to the unknot. Askitas claims that an inductive proof exists that all 2-cables of (2p+1, 2) torus knots are 4-move reducible to the unknot. This project seeks to explore the inductive argument.

The Complement of Fermat Curves in the Plane
Ariel Setniker
Western Oregon University

A plane algebraic curve is a curve defined implicitly by a relation of the form \( f(x, y) = 0 \), where \( f(x, y) \) is a polynomial in \( x \) and \( y \). A curve is said to be rational if it can be parametrized by rational functions \( x(t), y(t) \). In this talk we will discuss necessary conditions for a rational curve to be defined on the complement of high degree algebraic Fermat curves.
Points on a Circle with Integer Distances to Vertices of an Inscribed Equilateral Triangle
Sarah Ritchey
Youngstown State University

Given a circle and inscribed equilateral triangle with integer side lengths, we provide a solution to
the Pi Mu Epsilon Journal problem #1245 prepared by S. Rabinowitz, showing that there exists a
point on the circle with integer distances to the two closest vertices of the triangle.

Proofs Using Complex Numbers
Bradley Slabe
Youngstown State University

In this presentation, we use methods of complex numbers to prove two theorems of geometry,
Euler’s Triangle Theorem and Ptolemy’s Theorem. We finish by using residue theory to evaluate
some infinite series.
Using Differential Algebra to Solve Differential Equations
Daniel White
Fordham University
Most approaches to solving systems of differential equations rely on numerical techniques from advanced calculus. We are using techniques from differential algebra to solve systems polynomial equations that arise from systems of ordinary systems of differential equations symbolically by using the Dixon Resultant.

Bifurcation and Non-convergence in Hansen-Patrick’s Root Finding Method
Preston Hardy
St. John’s University
Hansen-Patrick’s root finding method is a family dependent on a single parameter alpha. It is known there are polynomials for which these methods do not converge to a root, but instead converge to an attracting period \( n \)-cycle. We explore what happens to these cycles when the Hansen-Patrick parameter alpha varies.

Neither Rain, Nor Sleet, Nor Snow. What About the Internet?
HanQin (Caesar) Cai
St. Norbert College
The internet is having a profound impact on the United States Postal Service. The volume of “snail mail” sent in this country decreased by 42.36% from 2008-2009. In 2010, I participated in a group competition studying this effect and this talk will revisit and update our results.

A Scale, Some Coins, A Problem
Sarah Stiemke
St. Norbert College
This is a variation of the classic counterfeit coin problem. Given a collection of \( n \) coins of weights 1, 2, or 3 grams and a balance scale, we prove the minimum number of weighings needed to determine the weight of each coin is \( n \).
Contracting and Rotating Ellipses
Wilson Cheung
State University of New York at Geneseo
The correlation between the area of a region and the number of lattice points contained within it has been an ongoing area of interest in the field of number theory. The problem arises from Gauss’s Circle Theorem, which shows that the number of lattice points within a circle is approximately equal to the area of the circle. Previous results have determined an upper bound for the number of lattice points in the interior region formed by two hyperbolas. In this talk, we will generalize this result to the specific case of two ellipses and conclude that the area of the interior region formed by these ellipses has the same upper bound. We’ll describe how the area and the number of lattice points change under contractions and rotations. This is a joint research project with Patrick Rault.

Jacobian for $n$-Dimensional Quasipolar Coordinates - Easy Proofs in All Cases
Tan Nguyen
University of Nevada – Las Vegas
The $n$-dimensional quasipolar coordinates are defined as a generalization of the polar coordinates (2-d) and the spherical coordinates (3-d). A short elegant proof for the Jacobian of the $n$-dimensional quasipolar coordinates for the general case is introduced. The special case of $\theta_k = \frac{lk\pi}{2}$ ($l_k \in \mathbb{Z}$) for some $k = 1, 2, 3, \ldots, n - 1$ is covered separately using a method that we call a perturbative (not perturbation) method. The results are then applied for the evaluation of the quasivolume of the $n$-dimensional quasiball.
Characterization of Melanoma and Moles using Signature Curves, Invariant Histograms and Fractal Dimension

Jack Stangl, Aaron Rodriguez, and Rimi Bhowmik

University of St. Thomas

This presentation focuses on the mathematical detection and analysis of border irregularity in skin lesions, for the purpose of identifying malignant melanoma amongst benign moles. In particular, it utilizes three different methods. The method of Signature Curves is based upon the curvature and the derivative of curvature for a given skin lesion, the method of Fractal Dimension is based upon the box counting method, and the method of Invariant Histograms is based upon cumulative distance histograms. The border irregularity of known malignant melanoma samples are compared to the border of known nevi, or common moles. We propose that melanoma possess distinguishable border differences from nevi, often undetectable to the human eye. We utilize these mathematical methods to detect and quantize this difference for diagnosis.

Modeling Spiking in Neurons with a Poisson Process

Peter Wiese

Augustana College

In the nervous system, nerve cells communicate through changes in ion concentrations called action potentials, or spikes. These spikes have been recorded and studied to understand the change in their distribution due to the presentation of a stimulus. By using a Poisson process, it is possible to model the distribution of spikes in time. Based on physiological properties, changes in the model are made to account for both the absolute refractory period and bursting of spikes. We will present several different models implemented on a spread sheet, both of a single neuron and of small systems of neurons.
A Comparison of Optimization Techniques in an Artificial Neural Network Modeling Attentive Response to Threatening Stimuli

Benjamin Douglas Ritz
Clarkson University

Several artificial neural network architectures have been constructed to model the human brain’s attentive response to threatening and non-threatening stimuli. Multiple experimental trials have been conducted to measure the brain’s response to stimuli. We examine specifically experiments involving attentive response to visual or somatosensory stimulus. During these experiments, electrophysiological data regarding activity within different portions of the subject’s brain is collected. In the experiments, subjects are presented with a cue to direct their attention toward a particular expected stimulus. They then receive a stimulus, which may or may not be the cued stimulus, and record the stimulus they receive. From these experiments, we can refine the artificial neural networks to fit the electrophysiological data we collect.

These artificial neural network architectures are optimized to fit data from the physical experiments. Using optimization tools, model parameters are fit to these data. These parameters can vary from the strength of a particular connection in the architecture to the connections’ very existence. We examine both which model architecture best fits the electrophysiological data and which optimization tool achieves the best fit for each model. From this, we can determine not only which model is most plausible for describing the brain’s attentive response to threats, but additionally what optimization tools are best used for doing so.

Mathematical Modeling of Chromatography
Ted Samore
Rose-Hulman Institute of Technology

The estrogen receptor protein has important regulatory functions and contributes to breast cancer development. The purified protein exists in equilibrium between monomers and dimers. We performed size-exclusion chromatography and dimer exchange assay experiments for the ligand-binding domain of the protein. We also mathematically modeled the chromatography using nonlinear convection diffusion equations and then compared the results of the experiments with the simulations to estimate the association and dissociation rate constants for the purified protein.
Sickle cell anemia is a disorder caused by a mutation in DNA that replaces the nucleic acid Glutamic with Valine. This replacement causes a change in the characteristics of hemoglobin that allows the monomers, the simplest units of chemically binding molecules, to stick together. These chains of monomers, called polymers, distort the shape and properties of the red blood cell. The malformed cells do not efficiently pass through capillaries or transport oxygen to the body's tissues. In order to make these cells more effective, the polymers must be broken apart. The process of breaking polymers apart is called melting. In the referenced study, the melting was induced by immersing the polymers in a buffer solution containing carbon monoxide. The mathematical model of this process was produced in a separate study. The purpose of this paper is to analyze and reproduce the current mathematical model using various computational and numerical tools.

Spatio-temporal mapping (STM) is a two-dimensional diagram which allows a user to visualize a series of movements over a spatially moving field. STM can be utilized to analyze several biological applications, including but not limited to, gastrointestinal motility. We use image decomposition of the ST maps to fully understand the frequency of the intestinal contractions that occur within Danio rerio, also known as zebrafish. In addition, we can use STMs in order to create software that predicts valuable information such as the velocity and duration of each individual contraction. This can help accelerate future research pertaining to the origin of common digestive diseases and potential cures.
Graphs with Equal Domination Number and Identification Number
Julie Elizabeth Lang and Lindzey Brooke Thacker
Morehead State University
The domination number of a graph is the minimum cardinality of a subset of vertices $S$ such that all vertices are either in $S$ or adjacent to a vertex in $S$. The identification number is the minimum cardinality such that the intersection of $S$ with the closed neighborhood of each vertex is distinct. This presentation will discuss instances in which the domination number and the identification number are the same as well as a method of constructing such graphs.

Sum and Product Connectivity Indices of Single Cyclohexane Compounds
Katrina Bandeli
Montclair State University
This research deals with Product (Randc) and Sum Connectivity Indices of graphs of Single Cyclohexane Compounds called SCC graphs. These graphs of special interest are built from a single hexagon base along with long branches or trees. We are particularly interested in an SCC graph where the connection between the hexagon and the tree part is by one edge. Formulas are developed for the indices of certain types of such graphs. We compare such SCC graphs with those with attachments of a star or a path. We show that among these types of graphs the Randc index of the hexagon attached to a path is almost the largest, and the Randc index of the hexagon attached to a star is almost the smallest. It is known that the product index is one of the most successful molecular descriptors for structural-property and structural-activity relationship studies.

Minimum Exponential Dominating Sets of Cycles Connecting at One or Two Vertices
Amanda Bright
Westminster College
The purpose of this research is to explore the behavior of minimum exponential dominating sets of two separate and equal cycles when they are connected at one or two vertices. It is well known that the size of a minimum exponential dominating set for a cycle of size $n$ is $\lceil n/4 \rceil$ for $n \neq 4$ and 2 for $n = 4$. When two cycles of size $n$ are connected at one vertex, we are going to prove that the size of the resulting minimum exponential dominating set is $2\lceil n/4 \rceil - 1$ for $n \neq 4$ and 2 for $n = 4$. We are also going to discuss the conjecture that the size of the minimum exponential dominating set of two cycles of size $n$ which are connected at two vertices distance $d$ apart is given by $2\lceil n/4 \rceil - 1$ when $d < n \mod 4$ and $2\lceil n/4 \rceil - 2$ when $d \geq n \mod 4$. These results can provide valuable information in the research of exponential domination and in graph theory.
On $d$-modular Labelings of the Union of Two Cycles

Joseph Buchanan

Illinois State University

For positive integers $r$ and $s$, let $K_{r\times s}$ denote the complete multipartite graph with $r$ parts of size $s$ each. Let $G$ be a graph with $n$ edges, $d$ be a positive integer such that $d|2n$ and set $c = 2n/d + 1$. A $d$-modular $\rho$-labeling of $G$ is a one-to-one function $f: V(G) \rightarrow [0, cd)$ such that

$$\min(\{|f(u) - f(v)|, cd - |f(u) - f(v)|\} : \{u, v\} \in E(G)) = \{1, 2, \ldots, \left\lfloor \frac{cd}{2} \right\rfloor\} \setminus c\mathbb{Z}.$$ 

It is known that if a $z$-partite graph $G$ admits a $d$-modular $\rho$-labeling, then there exists a cyclic $G$-decomposition of $K_{c\times td}$ for every positive integer $t$ such that $\gcd(t, (z - 1)!) = 1$. We investigate $d$-modular labelings of the union of two vertex-disjoint cycles.

On 2-fold Graceful Labelings

Ellen Sparks

Illinois State University

Let $\mathbb{Z}$ denote the set of integers and $\mathbb{N}$ denote the set of nonnegative integers. For integers $a$ and $b$ with $a \leq b$, let $[a, b] = \{x \in \mathbb{Z} : a \leq x \leq b\}$. For a positive integer $k$, let $2K_k$ denote the 2-fold complete mutigraph of order $k$. Similarly, let $2[a, b]$ denote the multiset that contains every element of $[a, b]$ exactly two times. Let $G$ be a multigraph of size $n$, order at most $n + 1$, and edge multiplicity at most 2. A labeling of $G$ is a one-to-one function $f: V(G) \rightarrow \mathbb{N}$. If $f$ is a labeling of $G$ and $e = \{u, v\} \in E(G)$, let $f(e) = |f(u) - f(v)|$. A 2-fold graceful labeling of $G$ is a one-to-one function $f: V(G) \rightarrow [0, n]$ such that $\{f(e) : e \in E(G)\}$ is either the multiset $2[1, \frac{n}{2}]$ if $n$ is even or the multiset $2[1, \frac{n-1}{2}] \cup \{\frac{n+1}{2}\}$ if $n$ is odd.

A graph $G$ is said to be 2-fold graceful if it admits a 2-fold graceful labeling. It can be shown that if $G$ with $n$ edges is 2-fold graceful, then there exists a cyclic $G$-decomposition of $2K_{n+1}$. El-Zanati has conjectured that every tree is 2-fold graceful. We investigate 2-fold graceful labelings of various classes of graphs including several classes of trees.

Direct Sums for Graph Automorphisms

Michael Carlyle

Augustana College

A graph automorphism is a mapping from and to itself that preserves vertex adjacency. After a brief recap of fundamental ideas such as groups and graphs, we will present examples of graphs whose automorphism groups are “easy” to see, and then we will show graphs whose automorphism groups are direct sums. We will also show examples where the techniques of direct sums are not quite enough.
2:00–2:15

Harmonic Functions and Walk on Spheres
Harini Chandramouli, Nora Stack, and Brandon Reeves

*University of Pittsburgh, St. Mary’s College of Maryland, and Gonzaga University*

In this research we are looking at a classical Kakutani’s result on the connection between the Brownian motion, a form of random movement, and harmonic functions, which are solutions to the Laplace equation. Kakutani’s theorem is basically a generalization of the mean value property of harmonic functions. We will use this result to solve the Laplace equation in various regions with certain boundary conditions.

Walk on Spheres (WoS) is used to simulate the Brownian motion of a particle suspended in liquid. The average distance travelled by the particle (Einstein’s model), as well as the average time needed for the particle to hit the boundary of certain regions will be discussed. The distribution of the point of first encounter with the boundary of the region is of interest to us. We will discuss the rate of convergence of the Brownian motion to the boundary as well as the overall computational effort needed to estimate values of the harmonic function using the Monte Carlo algorithm.

2:20–2:35

Existence of Optimal Parameters for the Black-Scholes Option Pricing Model
Justin Ziegler

*Minot State University*

Finance is one of the most rapidly changing and fastest growing areas in the corporate business world. Because of this rapid change, modern financial instruments have become extremely complex. New mathematical models are essential to implement and price these new financial instruments. It is a fact that the world of corporate finance, once managed by business students, is now controlled by mathematicians and computer scientists. In this particular interdisciplinary approach, we focus on a ground-breaking result in finance via mathematics, so-called the Black-Scholes model, a widely used tool for valuing options. In this work, we show existence, uniqueness, and continuity of a weak solution with respect to parameters. In addition, existence of optimal parameters are derived.
2:40–2:55

**Censored Distributions in Stochastic Simulation of Financial Market Data**

Valentina M. Semenova  
*Dartmouth College*

Certain financial market data, such as interest rate and volatility, are non-negative. At the same time, they are often modeled by stochastic processes without lower bound, such as Ornstein-Uhlenbeck process. In order to make distribution more realistic, it is necessary to bound it at 0. There are 2 possibilities for bounding: censored distribution and truncated distribution. It is examined how use of truncated distribution modifies statistical moments and correlations. It will be shown that use of censored distribution within the stochastic modeling framework of interest rates and volatilities produce more realistic results than unbounded or truncated distribution. Financial data illustrations include short interest rates and volatilities of foreign exchange rates.

3:00–3:15

**Using Wavelet Transformations to Analyze Carbon Uptake**

Tyler J. Heaps  
*Augsburg College*

The objective of this study was to apply wavelet transformations to analyze long-term records of carbon uptake at different measurement sites throughout the United States. Wavelet transformations, such as the Haar wavelet transform (HWT), were used to compress the information and reduce the biased and non-useful data. The data were collected from Ameriflux, a network of tower sites that provide quantitative information throughout the United States, and analyzed using MatLab.

Wavelets are useful in modeling a time series on different time scales. The wavelet approach was helpful in analyzing the carbon uptake at a given site, which may have half-hourly data collected over many years. A key measurement analyzed was net ecosystem exchange (NEE), which measures the rate that carbon enters and leaves the ecosystem. The wavelet decomposed NEE was compared to wavelet decompositions of other environmental measurements such as incoming solar radiation and air temperature. My results indicate a moderate linear correlation between the incoming solar radiation and carbon uptake. The smaller differences of solar radiation tended to cause an efflux of carbon into the atmosphere over a 4-6 year period. In shorter time scales, there was no linear correlation between the air temperature and NEE, but over a larger time scale, the higher temperatures allowed for uptake of carbon by the biosphere. Future research would examine the robustness of our findings across a latitudinal gradient and sites with similar vegetation.
Positive Solutions to Singular Third Order Boundary Value Problems on Purely Discrete Time Scales
Ashley Martin and Courtney DeHoet
University of Tennessee at Martin

We study singular discrete third order boundary value problems with mixed boundary conditions over a finite discrete interval. We prove the existence of a positive solution by means of the lower and upper solutions method and the Brouwer fixed point theorem in conjunction with perturbation methods to approximate regular problems.
Thursday MAA Session #10 August 2, 2012

MAA Session #10 2:00P.M. – 3:55P.M.

Room: Meeting Room N

2:00–2:15

**Studying Robotic Mobility Using Inverse Kinematics with Two Different Techniques**  
Melody Mone’t Wilson, Denetra Lynette Porties,  
Kristen Danielle Edwards, and Chinae Edmonds  
*Central State University*

The study of robot mobility is important in determining the full capacity in which a robot can operate in any given space. Inverse kinematics in robotics uses an end-effector (robot hand) to calculate the joint angles needed to obtain the position of the end-effector. This study uses inverse kinematics to determine the joint angle mobility of a four degrees-of-freedom robot manipulator using two techniques: Groebner Basis Theory and the Denavit-Hartenberg Matrix. The presenters will use these techniques to analyze the geometry of the robot and solve for the unknown joint angles of the waist, elbow, and shoulder. Since robotic movement is similar to human movement, the presenters will discuss how these results can contribute to studies in human behavior.

2:20–2:35

**Towards a Tropical Proof of the Gieseker-Petri Theorem - Part 1**  
Dat Pham Nguyen  
*SUNY Stony Brook*

Tropical geometry allows for many of the properties of algebraic curves to be studied from a new perspective. Specifically, tropical geometry reduces divisors on a Riemann surface to divisors on a metric graph, which can be easier to work with. This technique has recently been used by Cools, Draisma, Payne, and Robeva to prove the Brill-Noether Theorem (originally proven by Griffiths and Harris) combinatorially. Our project uses the same technique as Cools et al. to provide a combinatorial proof of the rank one case of the Gieseker-Petri Theorem, which was originally proven by Gieseker in 1982.

This part of our talk details the background and motivation of our project.

2:40–2:55

**Towards a Tropical Proof of the Gieseker-Petri Theorem - Part 2**  
Shalin Parekh  
*SUNY Stony Brook*

Tropical geometry allows for many of the properties of algebraic curves to be studied from a new perspective. Specifically, tropical geometry reduces divisors on a Riemann surface to divisors on a metric graph, which can be easier to work with. This technique has recently been used by Cools, Draisma, Payne, and Robeva to provide a combinatorial proof of the Brill-Noether Theorem (originally proven by Griffiths and Harris). Our project uses the same technique as Cools et al. to provide a combinatorial proof of the rank one case of the Gieseker-Petri Theorem, which was originally proven by Gieseker in 1982.

In this part, we introduce the Gieseker-Petri theorem and our approach to a tropical proof of the rank one case.
Towards a Tropical Proof of the Gieseker-Petri Theorem - Part 3
Vyassa Baratham
*SUNY Stony Brook*

Tropical geometry allows for many of the properties of algebraic curves to be studied from a new perspective. Specifically, tropical geometry reduces divisors on a Riemann surface to divisors on a metric graph, which can be easier to work with. This technique has recently been used by Cools, Draisma, Payne, and Robeva to prove the Brill-Noether Theorem (originally proven by Griffiths and Harris) combinatorially. Our project uses the same technique as Cools et al. to provide a combinatorial proof of the rank one case of the Gieseker-Petri Theorem, which was originally proven by Gieseker in 1982.

In this part, we explain the graph used in our proof, and some of its properties.

Towards a Tropical Proof of the Gieseker-Petri Theorem - Part 4
Cristina Mata
*SUNY Stony Brook*

Tropical geometry allows for many of the properties of algebraic curves to be studied from a new perspective. Specifically, tropical geometry reduces divisors on a Riemann surface to divisors on a metric graph, which can be easier to work with. This technique has recently been used by Cools, Draisma, Payne, and Robeva to prove the Brill-Noether Theorem (originally proven by Griffiths and Harris) combinatorially. Our project uses the same technique as Cools et al. to provide a combinatorial proof of the rank one case of the Gieseker-Petri Theorem, which was originally proven by Gieseker in 1982.

In this part, we present our proof.

Conics in Taxicab Geometry and Extended Taxicab Geometry
Hope Snyder
*Washington & Jefferson College*

We analyze and classify conics in Taxicab Geometry. From the analysis, we can visualize and graph these conics before consulting computer software. We will also investigate the conics under Extended Taxicab Geometry, a model described by David Caballero used to simulate the spread of forest fires in Europe. The extended taxicab distance takes into consideration the diagonal distance to cells placed in opposite corners. This causes the shapes of the conics to become stranger than under Taxicab Geometry.
Using Stochastic Differential Equations to Model an Antibiotic-Resistant Infection
Alexandra Signoriello, Pamela Kirkpatrick, and Nicole Fiorentino
Ursinus College, Messiah College, and Muhlenberg College

This project emphasizes the use and comparison of stochastic modeling approaches to derive and analyze models for Vancomycin-resistant enterococci (VRE) infections in an intensive care unit. VRE infections have been linked to increased mortality and costs. Stochastic models are derived from a deterministic model that incorporates the difference between colonization and infection, the role of special preventive care treatment cycles, fitness cost, and antibiotic use. The ultimate goal is to determine the most efficient and economically favorable strategies to control VRE and prevent outbreaks.

Hextile Planar Isotopy and Reidemeister Moves
Andreana N. Holowatyj
Benedictine University

A hexagonal knot mosaic is a knot diagram that lies in a regular hexagonal grid in a particular way. We consider planar isotopies and Reidemeister moves that result from exchanging tiles in the grid. We call these moves hextile planar isotopies and hextile Reidemeister moves, respectively. We enumerate basic hextile planar isotopy moves in $n$-hextile regions and explore methods to catalog the infinitely many basic hextile isotopy moves. Furthermore, any hextile Reidemeister move is hextile planar isotopic to one of a set of finite moves.

There may be abstracts for this session received too late to appear in print.

Please refer to the MAA Student web page at:
http://www.maa.org/mathfest/students.cfm
for presenters’ names, talk titles, and abstracts.
Exploring How Network Homophily Relates to Subgroup Calculation
Jeffrey Nielsen
United States Military Academy

Homophily in a network is a measurement of the extent to which individual nodes create links with nodes of similar attributes more often than those unlike themselves. A subgroup is a collection of nodes within a network that are more closely linked to each other than the rest of the network. After defining these terms and discussing how they are calculated, this talk explores whether homophily in a network might drive its subgroup formation by correlating homophily at the node level with the homophily of any subgroup containing that node. This correlation could inspire a search for an analytical relationship between homophily and subgroup creation, and therefore open a new set of research topics within network science. This project analyzes a data set consisting of 140 cadets of the United States Military Academy and centers on homophily by gender while using both a top-down and bottom-up algorithm for subgroup calculation.

Linkless Embeddings of Permutation Graphs
Joshua Wilson
SUNY Potsdam/St. Olaf College

Let $G$ be a graph on $n$ vertices, and let $\alpha$ be a permutation of the vertices of $G$. Drawing inspiration from the Petersen graph, Gary Chartrand and Frank Harary in their 1967 paper “Planar Permutation Graphs” define the $\alpha$-permutation graph of $G$, $P_\alpha(G)$, to be the graph formed by taking two copies of $G$ and joining a vertex $v$ of the first copy of $G$ to the vertex $\alpha(v)$ of the second copy of $G$. Under the hypothesis that $G$ is 2-connected, they find necessary and sufficient conditions for $P_\alpha(G)$ to be planar. In our work we seek to extend their results to linkless embeddings. A linkless embedding of a graph is an embedding so that every pair of disjoint cycles form a split link. We work on finding necessary and sufficient conditions for $P_\alpha(G)$ to have a linkless embedding.

There may be abstracts for this session received too late to appear in print. Please refer to the MAA Student web page at:
http://www.maa.org/mathfest/students.cfm for presenters’ names, talk titles, and abstracts.
Is Elliptic Curve Cryptography Secure?
Mehak Sandhu and Gonzalo Landeros
Benedictine University

Several public key cryptographic methods like the Diffie-Hellman key exchange and the ElGamal cryptosystem are based on the Discrete Logarithm problem. If we try to solve the DLP using the trial and error method, it takes exponential time. There are faster ways to solve the DLP in $\mathbb{F}_p^*$ with multiplication, however the best known algorithm is subexponential. The DLP problem for elliptic curves (ECDLP) is believed to be even more difficult; using the currently known algorithms it takes exponential time to solve this problem. Therefore companies like BlackBerry use Elliptic Curve Cryptography in some of their operations. But the cat and mouse game of crypto goes on. Recently in April 2012 there was a paper that challenges the statement that there is no subexponential algorithm to solve the ECDLP. In this expository work we attempt to understand the underlying mathematics behind some of these techniques in the rapidly evolving field of cryptology.

Star Studded Mathematics
Mark Kleehammer
SUNY Fredonia

In this talk we will explore the interior angle sum of stars. We will look at complete stars and apply the results to prove Barbier’s Theorem for Reuleaux Polygons.

There may be abstracts for this session received too late to appear in print.
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http://www.maa.org/mathfest/students.cfm
for presenters’ names, talk titles, and abstracts.
Riemannian Geometry and a Little Ricci Flow  
Taylor Klotz  
University of Colorado at Colorado Springs  

This talk will focus on presenting some of the most fundamental parts of Riemannian Geometry. Particularly those concepts needed to understand a rather useful idea known as Ricci flow. Riemannian manifolds, connections, Christoffel symbols, and the curvature tensors will be presented (rather quickly) so that we may begin to explore the elementary ideas of the Ricci flow equation. If time permits, a few examples of solutions to the Ricci flow equation will be presented, and their geometric implications will be discussed. If possible there will also be a brief aside on the use of the Ricci flow equation in Perelman’s proof of the Poincaré conjecture.

On the Equilateral Dimension of Complete Riemannian Manifolds with Bounded Curvature  
Jeremy Mann  
Johns Hopkins University  

The equilateral dimension of a given metric space is the maximum number of points that are all the same distance from each other. For spaces of constant curvature, such as the $\mathbb{R}^n$ and $S^n$, the equilateral dimension is purely a function of the space’s dimension as a manifold, $n + 1$ and $n + 2$, respectively. My results use various Comparison Theorems that give an upper bound on the equilateral dimension under various bounds on the Ricci or sectional curvature.

There may be abstracts for this session received too late to appear in print.  
Please refer to the MAA Student web page at:  
http://www.maa.org/mathfest/students.cfm for presenters’ names, talk titles, and abstracts.
Thursday Pi Mu Epsilon Session #3 August 2, 2012

PME Session #3 4:00P.M. – 6:15P.M.

4:00–4:15

Low Dimension Lie Algebra Dimension Reduction by Modding by the Center
Nick Benthem
Grand Valley State University
We investigate reducing the order of real low dimensional Lie algebras by modding by the center. We find the isomorphism between the reduced algebra and one of the non-decomposable Lie algebras and explain why in certain cases the reduced algebra decomposes.

4:20–4:35

Markov Chains in Literature: Re-Exploring Markovs Original Applications Using Modern Technology
Anne French
Austin Peay State University
Markov chains have numerous applications throughout mathematics and science, which is something the creator of the chains never thought was possible. Andrey A. Markov thought that his chains would only be applicable in the exploration of literature. His love of poetry led him to use Markov chains to study the alteration of vowels and consonants in Russian literature as a hobby. This presentation demonstrates how the analysis of literature using Markov chains and computer programming can be used to reveal the origination of the nonsense texts of the mathematician Charles Dodson, who is also known as Lewis Carroll.

4:40–4:55

Investigating the Mapping Properties of a Certain Class of Harmonic Functions on the Unit Disc
Cory Medin
Austin Peay State University
A good departure point for investigating harmonic polynomials is to study certain classes of harmonic functions. In particular, we compare the mapping properties of a certain family of harmonic functions with the mapping properties a certain family of Schlicht functions on the unit disc.

5:00–5:15

Benford Melodies: A Senior Thesis on Stochastic Composition
Nathaniel Card
Carthage College
Benfords Law can be applied to many things: addresses, stock prices, and river lengths; however, in this presentation we will explore using Benfords Law to both analyze and create melodies. The principal question being thus: do most melodies follow Benfords Law by the very nature of musical composition and counterpoint, or would composing melodies using Benfords Law create truly original sounding stochastic music.
5:20–5:35

**An Analysis of Blackjack Switch**  
Heather Cook  
*Roanoke College*

Blackjack Switch is an alternative to Blackjack. Each player is dealt two hands and after the second card for each is dealt, the player may switch those two cards. We will discuss changes to Blackjack basic strategy along with other results about the game of Blackjack Switch.

5:40–5:55

**A Pictoral Introduction to Knot Theory**  
Timothy Yeatman  
*University of South Florida*

Mathematicians have trouble distinguishing knots from each other. Knot invariants allow us to determine whether two knots are different. This talk will pictorially introduce the concept of a mathematical knot, and describe some of the methods used.
Niven Numbers and Cryptography
Sarah Wesley
Elmhurst College

A Niven number, also called a Harshad number, is a positive integer in any given base that is divisible by the sum of its digits in that given base. When looking at a Niven number \( m \), we can find the sum of its digits and divide the number by the sum of its digits to produce either another Niven number or a non-Niven number. This process can be repeated to produce a chain of equivalent integers until the chain terminates at a non-Niven number or stabilizes at a Niven number. This process has connections to the field of cryptography by establishing patterns of certain Niven numbers and the equivalency chains they produce.

Universal Niven Number Representations
Marissa Clougher
Elmhurst College

A positive integer is a Niven or Harshad number when it is divisible by the sum of its digits. A representation of a number is universally Niven if the representation is a Niven number in all standard bases. A procedure for generating universally Niven numbers is given using modular arithmetic.

The Derivative, the Integral, and Insect Development: Using a Biological Example to Teach Fundamental Calculus Concepts
Kristen Bosch
Hope College

In Calculus courses, students are often first presented with geometric and physical examples to motivate the concepts of the derivative and the definite integral. I will discuss a real-world biological application-modeling insect development time-that can be introduced early on in Calculus courses to provide additional context for these fundamental ideas.

When Prisoners Enter Battle
Sarah Heilig
New York University

I will show the results I found researching the connections between the twelve symmetric \( 2 \times 2 \) games. The twelve games can be shown on a 2D \( x - y \) axis and can be separated into six different sectors. In each section, the games involved can be manipulated to one common game. I will demonstrate how I was able to find one universal game in each sector, proving that these are more closely related than mathematicians previously believed.
5:20–5:35

**A Map Through ‘The Elements’**

Tyler Brown  
*Penn State Harrisburg*

This project has two major goals: Read the 13 books of Euclid and map out the dependence of each of Euclid’s theorems on the Axioms and previously proven theorems. Having collected a complete mapping of the dependencies to create software which can read the data we collect and render it graphically; specifically as a directed graph which shows visually how each theorem depends on those theorems which came before it. Our intention is to create software which is independent of The Elements itself so that it could also be used to map and display the dependency structure of other fields of mathematics, or any other sets of ideas which have a structure of dependence between them. This work was the joint research of Tyler Brown, Siddharth Dahiya, and Joseph Roberge.

5:40–5:55

**The Abstract and the Absurd: Lewis Carroll’s Reaction to Contemporary Mathematics**  
Justin Brockmann  
*University of Wisconsin - Whitewater*

Lewis Carroll (Charles Dodgson) was a staunch defender of traditionalism in mathematics. Some of the characters and dialogue he used in his Alice books can be seen as a reaction to the alterations of the mathematical landscape.

6:00–6:15

**Symmetry Means Beauty . . . Even In Nature**  
Emarus Shay  
*Austin Peay State University*

Geometry leads to interesting concepts and beautiful things in life. Considering distance-preserving transformations of the plane, and the set of all symmetries of planar objects, we show both form groups under composition of transformations. Specifically, the symmetry group of a regular $n$-gon is the Diheadral group, $D_n$, of order $2n$. 
Using Mathematical Modeling and Statistical Analysis to Relate Development Time and Temperature in Bean Beetles
Amanda Schuiling
Hope College

The success of a species within their environment is largely dependent upon its developmental timing. In insects, temperature plays a key role in determining rates of growth and development for various life stages including the embryonic stage. Thus time-lapse photography was used to measure the timing of this stage for bean beetles at various temperatures in the laboratory. Mathematical models were developed to fit these data, and statistical analyses were performed to provide a deeper understanding of the relationships between developmental timing and temperature in insect populations.

Two-Prey, One-Predator Model with Impulsive Effects for Integrated Pest Management
Spencer Havis
Benedictine University

We investigate a one-predator, two-prey model for integrated pest solutions. The model features stage structure for all species and birth pulses for the prey species. The birth Pulses, spraying of pesticides, and predator augmentation occur periodically. We establish conditions for which the model exhibits a total pest eradication solution, solutions which one prey is eradicated, and permanent solutions in which all species are maintained.

Pattern Formations by Social Interactions During Foraging
Weici Hu
Smith College

Different foraging behaviors and social interactions within a group of animals can form interesting spatio-temporal patterns of foragers and food distribution. Using a system of partial differential equations, we model the movement of foragers which includes random walk and attraction towards prey, as well as the prey movements. We started with a simple forager-prey system and showed it always settles into a spatially uniform steady state. We then investigated the effect of social interactions, in particular we consider two groups of foragers with different behaviors: those who look for prey independently ("foragers") and those who exploit others ("exploiters"). We found that the forager-exploiter-prey (FEP) system exhibit spatiotemporal oscillations. We then further studied other possible social interactions between foragers and exploiters, such as the aggressiveness exhibited by the exploiters towards the foragers, and the switching behavior between the foragers and exploiters. While the aggressive behavior of the exploiters tends to stabilize the system, the switching behavior alters the frequency and pattern of oscillation.
9:30–9:45

Mathematical Models of Ant Territorial Boundaries Relating to Aggression
Evan Tomkiewicz and Jessica Burl
Clarkson University

Aggression has always been one of the key determinates in territorial boundaries, not only in humans but also in simpler animals such as ants. Formica subsericea, or shiny black ants, make large mounds in abundance in St. Lawrence County in New York State. A collection of data was taken to get spatial arrangements of individual ant colonies in a field. ArcGIS was used to determine the distances between each colony and create a visible map of all of the data points. Different statistical error methods were applied to check the accuracy of our mathematical model that used tessellations to estimate possible boundary outlines of every colony. The accuracy was further tested by various experiments completed in the field. After that, individual ants were taken from different colonies to analyze aggression levels depending on the distances between their individual colonies. We predicted that closely neighboring colonies would display less aggression compared to farther distanced colonies.

9:50–10:05

Analysis of Diatoms and Arcellacean Death Assemblages
Cory Ali and Illian Rojas
University of Houston - Downtown

In this project, diatom and arcellacean death assemblages were studied to determine if consistent trends exist in the succession of a mitigation wetland ecosystem in Greens Bayou Wetland Mitigation Bank compared to a stable wetland ecosystem in the Anahuac National Wildlife Refuge. The statistical package R (a language and environment for statistical computing and graphics) was used to calculate the various statistical indices used to determine alpha and beta diversity between GBWMB and ANWR. R was used to analyze the raw data and alternatively, the rare species in the diatom and arcellacean assemblage were removed using the theory of listwise deletion and then analyzed by R. The comparison of traditional missing data analyses such as listwise deletion, partial listwise deletion, imputation, and partial imputation via SAS to the inclusion and exclusion of rare genera results used by R were compared to analyze the impact of the rare genera of the diatom and arcellacean death assemblage. This missing data analysis shows that the inclusion of rare genera is important to the succession signal in the mitigation wetland.

10:10–10:25

A Mathematical Model of Prairie Restoration
Michael Frank, Courtney Sherwood, and Lauren Tirado
Simpson College

We present a differential equations model of prairie restoration. Here, species richness is considered as an indicator of prairie restoration, with the variables for the equation being species richness and time. We will incorporate field work from a prairie in Nebraska as an example of our model.
Combinatorial and Computer Proofs of Certain Identities
Michael Weselcouch and Sean Meehan
Assumption College and University of Notre Dame
In this talk we will present combinatorial and computer assisted proofs of certain interesting identities. This research was conducted as part of the 2012 REU program at Grand Valley State University.

Analysis of Sudoku Variations Using Combinatorial Techniques
Ellen Borgeld and Elizabeth Meena
Grand Valley State University and Trinity Christian College
Many people enjoy solving Sudoku puzzles, but there are other challenging and intriguing questions about Sudoku that can be studied using combinatorics, such as counting the number of possible Sudoku boards and determining when a puzzle is solvable. Some variations on the standard $9 \times 9$ puzzle have different rules, for example, using arrows or other symbols between individual cells rather than numerical clues. We present the results of our research of Sudoku variations, using combinatorial counting techniques including permutations and equivalence relations. This research was conducted as part of the 2012 REU program at Grand Valley State University.

Conway’s Subprime Fibonacci Sequences
Julian Salazar
Henry Wise Wood High School
It’s the age-old recurrence with a twist: add the two preceding terms, and if the sum is composite, divide by its smallest prime divisor to get the current term (e.g., $0, 1, 1, 2, 3, 5, 4, 3, 7, \ldots$). This presentation is both an exposition on the properties of this interesting variant (namely, the existence of cycles reminiscent of the $3x + 1$ problem), and a retrospective on how a tri-generational trio approached and collaborated on it.

Famous Sequences and Euclidean Algorithm Step Sizes
Gregory James Clark
Westminster College
We will prove that the maximum number of steps for the Euclidean Algorithm is achieved using Fibonacci numbers and Lucas numbers of odd index. In particular, we will use a formula that provides an upper bound on the number of steps needed when using the Euclidean Algorithm on two natural numbers, $a$ and $b$. Furthermore, we will show that the upper bound is achieved for certain values of $b$. 
Given a positive integer \( k \) and two multisets, \( A \) and \( B \), we say that \( A \) and \( B \) form a \( k \)-irreducible pair if:

1. the elements in \( A \) and \( B \) are integers in \( \{1, 2, \ldots, k\} \),
2. the sum of all the integers in \( A \) is equal to the sum of all the integers in \( B \), and
3. there is no proper subset of integers in \( A \) such that the sum of the integers in this subset is equal to the sum of the integers in some subset of \( B \).

In our research, we study the problem of \( k \)-irreducible pairs, and, more precisely, the maximum length, \( l(k) \), of a \( k \)-irreducible pair. Thus, \( l(k) \) is that maximum size of the sum of the sets \( A \) and \( B \), that satisfy the conditions for \( k \)-irreducibility. It can be shown that \( l(k) \) is at least \( 2k - 1 \). It is also conjectured that \( l(k) = 2k - 1 \).

In this talk we will present the work completed in the summer of 2012 during the Dr. Albert H. and Greta A. Bryan Summer Research Program at Simpson College. We are furthering the analysis of the card game Beggar-My-Neighbor specifically with the intent of discovering a deal that leads to an infinite game in a 52-card deck. We are using combinatorics and programs written in Mathematica to examine and refine the large number of possible deals based on structures that lead to cyclic behavior.
Generalized Homological Sequences on Simplicial Complexes
Brian Green, Alex Onderdonk, Kim Rich, and Mike Agiorgousis
Ursinus College, Immaculata University, Bucknell University, and Ursinus College
We define a notion of homological equivalence of discrete Morse functions on simplicial complexes, generalizing a previous notion of equivalence of discrete Morse functions on graphs based on the homology groups of the complex. We show that these sequences are well behaved, and construct discrete Morse functions which yield prescribed integer sequences.

An Alternative Definition for the Conley Relation
Junnan He
Australian National University
In the theory of dynamics of closed relations on compact Hausdorff spaces, the definition for the Conley relation $f^\Omega$ of an iterated closed relation $f$ is nontrivial. This paper establishes a new equivalent definition for $f^\Omega$, and discusses its interpretation.

Cost-Conscious Voters in Referendum Elections
Lindsey Brown and Hoang Ha
Baker University and Bryn Mawr College
In referendum elections, voters are often required to register simultaneous “yes”/“no” votes on multiple proposals. The separability problem occurs when a voter's preferred outcome on a proposal or set of proposals depends on the possible outcomes of other proposals in the election. Previous research has identified cost-consciousness—that is, a desire to limit total public expenditures—as a potential cause of nonseparability in referendum elections. In this talk, we will present new models of cost-consciousness and explore both their theoretical and practical implications. This research was conducted as part of the 2012 REU program at Grand Valley State University.

Tight Lower Bounds for Unequal Division
Andrew Lohr
University of Maryland
Alice and Bob want to cut a cake; however, in contrast to the usual problems of fair division, they want to cut it unfairly. More precisely, they want to cut it in ratio $(a : b)$. (We can assume $\gcd(a, b) = 1$.) Let $f(a, b)$ be the number of cuts this will take (assuming both act in their own self interest). It is known that $f(a, b) \leq \lceil \log(a+b) \rceil$. We show that (1) for all $a,b$, $f(a, b) \geq \log\log(a+b)$ and (2) for an infinite number of $(a,b)$, $f(a, b) \leq 1 + \log\log(a+b)$.
Discrete Markov Chains and Candy Land
James D. Munyon
*Youngstown State University*

Discrete Markov chains were used to statistically analyze the pastime board game “Candy Land”. By viewing the game in such a mathematical way, much information relating to possible outcomes in a game can be determined. Such information includes: the probability of being on a space after a certain number of card draws, the average number of card draws in a single game, the minimum number of card draws to possibly win a game, and much more.

Fair Allocation Visualizations
Philip John Bontrager
*Goshen College*

Two or more people have equal ownership rights for several goods for which each person may have different monetary valuations. What is a fair way to allocate the goods among the people? This work examines different notions of fairness including efficient, proportionate, envy-free, share proportionate, and value proportionate. The goal is to develop visualizations to assist us and others to better understand notions of fairness and their interrelationships.

The “Bigger Half”: Examining Fair Division
Megan Chambers
*Youngstown State University*

The Fair Division Dilemma, also known as the “Cake-Cutting Problem”, is a method of resource allocation used to ensure that each party sharing the resource believes that they have received at least a fair share. It is a problem that has been studied extensively by mathematicians for years and has been the topic of many mathematical papers and books. In my presentation, I examine this problem and its many variations, as well as applications of the problem under different conditions. The potential uses for the problem are abundant, and the mathematics behind it are beautiful, not to mention delicious!
PME Session #5

Room: Meeting Room O 8:30A.M. – 11:45A.M.

8:30–8:45

**Sex-Dependent Deer Population Dynamics with Effects from Seasonal Harvesting**

Shane Wilson  
*Luther College*

We seek to formulate a sex-dependent population model for deer in Winneshiek County, aiming to determine the number of hunting licenses that should be issued in order to establish a stable population. Our assumptions are consistent with the life cycle of deer and the hunting licenses issued by the DNR.

8:50–9:05

**Evaporation Investigation**

Jacalyn Kulow  
*St. Norbert College*

We will investigate various factors of water fountain evaporation in order to determine a more practical way of calculating the amount of water lost in these decorations. Through research and calculations, it is possible to gain a better understanding and draw conclusions as to how much water is being wasted.

9:10–9:25

**From Golf Balls to Airplanes; What are the Powers of Dimples?**

Erik Miller  
*St. Norbert College*

Dimples are known to improve the performance of golf balls by extending the boundary layer over the surface. Could this principle be applied to airplane design? With the addition of dimpled airfoils, the performance of aircraft could be greatly improved. We’ll investigate the aeronautical theory behind the dimples and see how it could affect the phases of flight.

9:30–9:45

**Modeling the Population Dynamics of Phytoplankton in Freshwater Ecosystems**

Jeff LaJeunesse  
*St. Norbert College*

We investigate the population dynamics of phytoplankton, which form the base of aquatic ecosystems. Predicting phytoplankton growth contributes to a better understanding of climate change. We focus on how light availability, particle geometry, and fluid mixing affect changes in the population by using field data, laboratory data, and scientific computation.
9:50–10:05
**Goursat’s “Other” Theorem: A Complete Characterization of a Direct Products Subgroups**
Daniel Catello
*Youngstown State University*

An elementary abstract algebra course teaches students many methods of constructing, analyzing, and dissecting groups. However, most texts and courses in this field exclude this intriguing theorem by Jean-Baptiste Goursat that fully characterizes the subgroups of a direct product. The theorem utilizes a surprising number of topics covered in a first abstract algebra course. Goursat’s “other” theorem will be proven and dissected through some examples.

10:10–10:25
**Significant Scientific Studies Made Aboard the International Space Station**
Kathleen Karika
*Texas A&M University*

The ISS is a joint venture between five national space agencies whose goal is to discover in space what could otherwise never be determined from Earth. Using data analysis and mathematical modeling, a production function was developed to predict what influences a scientifically significant experiment.

10:30–10:45
**Nesting Index for Assembly Words**
Ryan Arredondo
*University of South Florida*

Ciliates are organisms which undergo massive recombination of DNA. A particular model for this recombination process uses structures called assembly graphs which can be represented by double occurrence words (assembly words). Patterns arise in the representations of certain scrambled genes. We use these patterns to define a nesting index for assembly words.

10:50–11:05
**Outer Automorphisms of \( S_6 \)**
Mario Sracic
*Youngstown State University*

If \( G \) is a group, and \( \phi : G \rightarrow G \) such that \( \phi \) is one-to-one, onto, and a homomorphism, then \( \phi \) is called an automorphism of \( G \). Moreover, \( \phi \) belongs to the group of automorphisms of \( G \), denoted \( Aut(G) \). Once defining the inner and outer automorphism groups, \( Inn(G) \) and \( Out(G) \), respectively; we will focus on proving

\[
|Out(S_6)| \geq 2.
\]  

(1)

This theorem is necessary to show \( Out(S_6) \cong \mathbb{Z}_2 \). We will prove (1) through applications of group actions and the Sylow Theorems.
11:10–11:25
Mathematical Model for the Metabolic Pathway of the Butanol Fermentation
Estee George
Youngstown State University
The bacteria, Clostridium beijerinckii, ferment sugars to produce solvents like acetone, butanol, and ethanol for use as alternative fuels. The fermentation process can be modeled by a system of differential equations based on metabolic reactions using Michaelis Menten enzyme kinetics. The equations can be analyzed and numerically solved to explore the efficient conversion of glucose and xylose into butanol by these bacteria. The mathematical model predicts the concentrations of intermediaries and products formed, and results are compared to experimental data.

11:30–11:45
Science Fiction to Reality: The Influence of Interaction Rates, Flesh Decay, and Detection Rates in the Zombie Apocalypse
Frances Withrow
Texas A&M University
A zombie is considered to be the living dead, and of the realm of science fiction. However, in our generation zombies are commonly found in books, movies, and television shows. In this paper we use mathematical modeling to analyze a zombie outbreak. The ultimate goal was to develop a model that had a stable disease free equilibrium. We started with a previous model and developed new models that included concepts such as flesh decay, saturated interaction rates, and human detection rates. We included a sensitivity analysis of one of the new constants. None of the models had a stable disease free equilibrium; however, the most successful models were those that included some combination of saturation and detection rates. This implies that the best way to save humanity would be to decrease the number of humans a zombie can interact with and increase the rate of zombie detection per human being.
The traditional game of Nim comprises of two players removing objects from distinct piles, and the player who takes the last object loses. We consider the game Nim on Cayley graphs of finite groups. We examine winning strategies for Nim on Cayley graphs of cyclic, dihedral, and abelian groups.

One famous problem is the graph coloring problem: given a simple graph, what is the fewest number of colors required to color the vertices of the graph such that no adjacent vertices are the same color? It turns out that the number of \( \lambda \)-colorings of a graph \( G \) can be described by a polynomial \( \chi_G(\lambda) \), referred to as the chromatic polynomial of \( G \). Recent research has begun to establish relationships between \( \chi_G(\lambda) \) and what is known as the coloring complex of \( G \). In particular, we will be examining coloring complexes of hypergraphs—graphs where edges may connect more than two vertices.

For the research we conducted this past summer, we wrote a Sage program that computes information pertaining to the topology of the coloring complex and chromatic polynomial of an inputed hypergraph. We then attempted to use this data to make and prove conjectures about the relationships between these two objects. In this talk, we will formally define the above concepts, describe the capabilities of our program, and discuss the results we were able to establish.

A columnar transposition cipher is an encryption technique that permutes the characters of a message using positions in a rectangular enciphering grid. In this project, we investigate the existence and location of fixed points of the underlying permutation as they relate to the number of columns and message length used.

This presentation examines relationships between visual representations of partitions, called Ferrers diagrams, and shapes called border strips. First, we examine the properties of border strips contained within Ferrers diagrams, then the properties of border strips appended to Ferrers diagrams, and finally the properties of border strips independent of Ferrers diagram.
9:50–10:05

**Partially Ordered Sets of Commutative Catalan Interpretations and the Bivariate Catalan Generating Function**

Heather Kitada  
*Lewis & Clark College*

We will demonstrate several interpretations and bijections of sets of objects enumerated by the Catalan numbers: Dyck paths, rooted plane trees, binary trees, nonintersecting arcs, Temperley-Lieb Diagrams, and 312-avoiding permutations. Many of these objects are characterized by binary characteristics; however, we will also show more complex structures with applications in abstract algebra. Finally, we will explore single and bivariate Catalan generating functions that utilize statistics on Dyck paths, namely bounce and area.

10:10–10:25

**A Generating Function for Inversions on Pattern Avoiding Involutions**

Ashley Broadwell  
*Pepperdine University*

The generating function for inversions on 312-avoiding permutations is given by the $q$-Catalan polynomial $C_n(q)$ and can be determined by using the area statistic on Dyck paths. In this talk, we will discuss the generating function for inversions on 312-avoiding involutions by using a certain subset of Dyck paths.

10:30–10:45

**A Combinatorial Representation of Pattern Avoiding Involutions**

Joshua Thornton  
*Pepperdine University*

Permutations that avoid the pattern 312 are known to be counted by the Catalan numbers and can be represented combinatorially as Dyck paths. In this talk, we will discuss pattern avoiding involutions and give a combinatorial representation of these involutions as certain types of Dyck paths.

10:50–11:05

**Fibonacci Numbers of Paths, Cycles and Combs**

Emily Sasala  
*Washington & Jefferson College*

The talk explores the Fibonacci numbers of paths, cycles and combs. The Fibonacci number of a graph corresponds to the number of independent vertex sets in that graph. We then discuss relationship between the Fibonacci number of cycles and the golden ratio and determine a recursive formula for combs.
11:10–11:25

**Coloring the Platonic Solids**  
Danielle DeChellis  
*Youngstown State University*

In this talk, we explore two different approaches to determining the number of ways to color the vertices of the Platonic solids. The first approach utilizes edge reduction and a matrix representation of the geometrical figures. The second approach implements traditional graph theory concepts to derive the chromatic polynomial. Both methods lead to the development of the chromatic polynomial, which is used to find the number of ways to color the vertices of the Platonic solids.

11:30–11:45

**Mathematical Modeling of Selenium Metabolism in S. maltophilia ORO2.**  
Matthew Pierson  
*Youngstown State University*

A system of differential equations was developed using a modified logistic growth equation coupled with Michaels-Menten enzyme kinetics to model bacterial growth and selenite metabolism in *S. maltophilia* ORO2. The model tracks selenite as it enters the cells and is reduced to nontoxic selenium. Analysis and numerical computation of the model compare favorably to experimental data, and help explain this bacterias resistance to selenite.
The Effects of a Grace Period in a Multi-Stage Vaccine
Katherine Hunzinger
Benedictine University
Mathematical models are utilized to predict how a disease will spread and how to slow down its spread; this is important because it is unethical to test disease spread on a human population. We will be utilizing a model based on the SIR model to represent a disease’s spread with the use of a multi-stage vaccine graphically and mathematically. Once we have found the proper parameters to represent the effectiveness and necessity of a multi-stage vaccine in order to eradicate a disease in a population, we can begin to analyze a few things. The goal of this project is to determine the effectiveness, or ineffectiveness, of a multi-stage vaccine when a controlled grace period is implemented amongst the population of study.

The Dynamics of an SVEIR epidemic model with Pulse Vaccination
Farina Kanwal
Benedictine University
We investigate the dynamics of an SVEIR model with pulse vaccination. We establish conditions based on the basic reproduction number, for which the model has a globally attractive infection free periodic solution and for which the disease persists.

Effects of a Dynamic Population in a Multi-Stage Vaccine
Kiran Munir
Benedictine University
Epidemiology calls for mathematical models to reveal results of hypothetical situations in order to slow the spread of disease. Unlike other branches of science, conducting an experiment by deliberately spreading disease to obtain results about the spread and the effectiveness of a vaccine would be unethical. Furthermore, some diseases require multiple shots with pre-determined time between them in order to be fully effective. In such a case, studying the effectiveness of vaccine in a given population saves resources while helping strategize the best usage of the limited vaccines. In this research project we will discuss instances for both a constant and a changing population.
3:00–3:15

Construction of Generalized Minimum Aberration Designs of size 36, 40 and 44
Laura M. White
Arkansas State University

Regular fractional factorial designs are widely used experimental designs for studying effects of two or more variable simultaneously, but leave large gaps in run size. Non-regular fractional factorial designs can be constructed for every run size that is a multiple of four, which allows run size flexibility and economy. My research will focus on construction of optimal designs of size 36, 40, and 44 runs using graphic processing unit (GPU) technology, with a primary objective of providing, for the first time, comprehensive design tables for the best 36, 40, and 44 runs designs available. Creating design tables make it possible for engineers and scientist to plan experiments for any combination of runs and number of variables to be studied.
MAA Session #20
Room: Meeting Room L
2:00P.M. – 3:55P.M.

2:00–2:15

Security of a MAC Utilizing the Non-Associative property of Quasigroups
Natalia Poniatowska
Benedictine University

A Quasigroup is a set of elements with one binary operation whose multiplication table forms a Latin square. These algebraic structures are similar to groups; however they are not required to be associative. This non-associativity has many applications, one such area is Cryptography. A widely studied and used cryptographic tool is Message Authentication Code, MAC. In this talk I discuss a type of a MAC, called QMAC, which was introduced by Meyer. I will focus on properties of quasigroups including non-associativity and the generalized notion of non-associativity that can be used to better understand the security of this scheme.

2:20–2:35

Investigations into the Fixed Points of Group Automorphisms
Kingston Kang
Randolph-Macon College

The main purpose of this presentation is to prove a conjecture mentioned in the paper, On the Fixed Points of Abelian Group Automorphisms, published in Rose-Hulman Undergraduate Mathematics Journal 2010. In the paper, authors studied properties and developed formulae for \( \theta \), a function that records the order of each partition set of d-fixers \( S^G_d = \{ \alpha \in Aut(G) : |F_G(\alpha)| = d \} \), where \( d \) is a divisor of the order of an abelian group \( G \). In the end of the paper, authors proposed a formula for groups of the form \( \mathbb{Z}_p \times \mathbb{Z}_{p^2} \), where \( p \) is a prime, for all divisors \( d \) of \( |\mathbb{Z}_p \times \mathbb{Z}_{p^2}| = p^3 \).

2:40–2:55

Extensions of Finite Distributive Lattices
Tanya Riston
Penn State Erie, The Behrend College

A lattice is a partially ordered set where every pair of elements has a least upper bound and a greatest lower bound. Examples of distributive lattices include, but are not limited to, collection of open sets of a topological space and collection of ideals of a commutative ring. For a given distributive lattice \( L \), the concepts of prime elements, \( Spec(L) \), and minimal prime elements, \( Min(L) \), of \( L \) are of great importance and can be used to understand various lattice-theoretic properties.

In this talk we will discuss the space of \( Min(L) \) for a given finite distributive lattice \( L \). Furthermore, using \( Min(L) \) we will define various extensions of lattices, namely, rigid extension, \( r \)-extension, and \( r^n \)-extension, and results related to them. The ultimate goal is to answer an open question related to the extensions of finite distributive lattices: Is a rigid extension between finite distributive lattices equivalent to the \( r \)-extension?
There are many results on the properties and classification of groups, rings, and fields. These have led to the solutions of many well known problems in mathematics, such as insolvability of the general quintic equation and the impossibility of trisecting a general angle. Rings and fields are extensions of the group structure to two operations rather than one with both operations jointly obeying the distributive law. The content of this talk will be extending these definitions to three operations rather than two creating structures called 3-rings and 3-fields. We will cover some results on classification and properties of these new structures.
Visualizing Chaos with Negative Alpha Values
Margaret Peterson
College of Saint Benedict

Based on previous work by Andrew Nicklawsky and Bob Hesse, instead of plotting iterative root finding methods on a subset of the complex plane, we have created a map utilizing a third dimension in which the initial starting point is plotted on the \( z \)-axis, creating 3D images of spheres. These spheres are shaded in accordance to the speed at which a particular initial starting point converged, allowing us to analyze convergence, or more specifically, to explore the choice of addition or subtraction in the denominator of the iterative root finding methods. There are many theories as to how the choice of sign shall be chosen for positive alpha values; however, in the case of a negative alpha value, these theories do not hold. Using programs based off of those developed by Nicklawsky, we developed rules to dictate this choice between addition and subtraction in order to maximize the speed of convergence for negative alpha values.

Invariants of Complex Hypersurfaces
Lukas Owens and Camilo Montoya
Whitman College and Florida International University

A complex analytic set is locally defined to be the set of common zeros of a number of analytic functions. The intricate properties of complex analytic sets are unique to several complex variables since in \( \mathbb{C} \) any non-trivial complex analytic set is discrete.

In this talk we will study how properties of complex analytic sets that are naturally associated with a real-analytic hypersurface in \( \mathbb{C}^n \) shed some light on the properties of the hypersurface itself.

Parametric Equations for Video Games
Benjamin Paul Studer
Augustana College

Danmaku, manic shooters, and bullet hell shooters are video game genres that feature intricate patterns of bullets that the player must avoid. The motion of the bullets is determined by parametric equations of varying complexity. After identifying the fundamental components of a Danmaku pattern, we will use a game engine to produce these patterns through the use of parametric equations primarily in the polar coordinate system.
Polylinear Spline Interpolation

Ryan Anderson
Kennesaw State University

Linear splines, in particular interpolating splines, are used to approximate a function given a discrete set of values of the function. Linear splines are widely used in many applications targeting geometric modeling of curves and surfaces as they are generally easy to work with, as the properties of linear functions are well known. The concept of linear splines have been extended to bilinear and polylinear splines with many results having been proved. In this talk, I will introduce the concept of spline interpolation and discuss simultaneous approximation of a function (of certain smoothness) and its derivatives by splines as well as present some results on the error of approximation.
### J. Sutherland Frame Lectures

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<tr>
<th>Year</th>
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<td>Melanie Matchett Wood</td>
<td><em>The Chemistry of Primes</em></td>
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<td>2011</td>
<td>Margaret H. Wright</td>
<td><em>You Can’t Top This: Making Things Better with Mathematics</em></td>
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<td>2010</td>
<td>Nathaniel Dean</td>
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<td>2009</td>
<td>Persi Diaconis</td>
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<td>2008</td>
<td>John H. Conway</td>
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<td>2007</td>
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<td>2006</td>
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<td>2005</td>
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<td>Joan P. Hutchinson</td>
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<td>1980</td>
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Pi Mu Epsilon would like to express its appreciation to the American Mathematical Society, the American Statistical Association, the Committee for Undergraduate Research, the Society for Industrial and Applied Mathematics, Budapest Semesters in Mathematics, the SIGMAA-Environmental Mathematics and BioSIGMAA for the sponsorship of the Awards for Outstanding Presentations. It would additionally like to thank the National Security Agency for its continued support of the student program by providing subsistence grants to Pi Mu Epsilon speakers.
MAA Lectures for Students

2012  Ivars Peterson  Geometreks
2011  Roger Nelson  Math Icons
2010  Sommer Gentry  Faster, Safer, Healthier with Operations Research
2009  Colm Mulcahy  Mathematic with a Deck of Cards on the Interval Between

   5.700439718 and 806581751709438785716606368564037
   669752895054088327782400000000000000

2008  Laura Taalman  Sudoku: Questions, Variations and Research
2007  Francis Edward Su  Splitting the Rent: Fairness Problems, Fixed Points, and

   Fragmented Polytopes
2006  Richard Tapia  Math at Top Speed: Exploring and Breaking Myths

   in Drag Racing Folklore
2005  Annalisa Crannell & Marc Frantz  Lights, Camera, Freeze!
2004  Mario Martelli  The Secret of Brunelleschi’s Cupola
2004  Mark Meerschaert  Fractional Calculus with Applications
2003  Arthur T. Benjamin  The Art of Mental Calculation
2003  Donna L. Beers  What Drives Mathematics

   and Where is Mathematics Driving Innovation?

   by Sir Randolph “Skipper” Bacon III
2002  M. Elisabeth Pate-Cornell  Finding and Fixing Systems’ Weaknesses:

   The Art and Science of Engineering Risk Analysis
2001  Rhonda Hatcher  Ranking College Football Teams
2001  Ralph Keeney  Building and Using Mathematical Models to Guide Decision Making
2000  Michael O’Fallon  Attributable Risk Estimation:

   A Tale of Mathematical/Statistical Modeling
2000  Thomas Banchoff  Interactive Geometry on the Internet
1999  Edward G. Dunne  Pianos and Continued Fractions
1999  Dan Kalman  A Square Pie for the Simpsons and Other Mathematical Diversions
1998  Ross Honsberger  Some Mathematical Morsels
1998  Roger Howe  Some New and Old Results in Euclidean Geometry
1997  Aparna Higgins  Demonic Graphs and Undergraduate Research
1997  Edward Schaefer  When is an Integer the Product

   of Two and Three Consecutive Integers?
1996  Kenneth Ross  The Mathematics of Card Shuffling
1996  Richard Tapia  Mathematics Education and National Concerns
1995  David Bressoud  Cauchy, Abel, Dirichlet and the Birth of Real Analysis
1995  William Dunham  Newton’s (Original) Method - or - Though This

   Be Method, Yet There is Madness
1994  Gail Nelson  What is Really in the Cantor Set?
1994  Brent Morris  Magic Tricks, Card Shuffling

   and Dynamic Computer Memories
1993  Richard Guy  The Unity of Combinatorics
1993  Joseph Gallian  Touring a Torus
1992  Peter Hilton  Another Look at Fibonacci and Lucas Numbers
1992  Caroline Mahoney  Contemporary Problems in Graph Theory
1991  Lester Lange  Desirable Scientific Habits of Mind Learned from George Polya

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