CUMC 2020 Schedule

*** All times are in Eastern Daylight Time (EDT). ***

	August 20th (Thursday)	**August 21st (Friday)**	**August 22nd (Saturday)**	**August 23rd (Sunday)**
10:30am – 11:00am	Opening remarks			
11:00am – 11:30am	Student talks	Student talks	Student talks	Student talks
11:30am – 12:00pm	Student talks	Student talks	Student talks	Student talks
12:00pm – 12:30pm	Student talks	Student talks	Student talks	Student talks
12:30pm – 1:00pm	Student talks	Student talks	Student talks	Student talks
1:00pm – 1:30pm	Keynote lecture: Dr. Lindi Wahl	Keynote lecture: Dr. Stephen Watt	Keynote lecture: Dr. Katherine Stange	Keynote lecture: Dr. Graham Denham
1:30pm – 2:00pm				
2:00pm – 2:30pm				
2:30pm – 3:00pm				
3:00pm – 3:30pm	Academia session: Dr. Rosalie Bélanger-Rioux	Industry panel	Student poster session	Student talks
3:30pm – 4:00pm				Student talks
4:00pm – 4:30pm	Keynote lecture: Dr. Dror Bar-Natan	Keynote lecture: Dr. Chris Kapulkin	Keynote lecture: Dr. Ting-Kam Leonard Wong	Keynote lecture: Dr. Carlo Lisi
4:30pm – 5:00pm				
5:00pm – 5:30pm				Closing remarks
5:30pm – 6:00pm				
6:00pm – 6:30pm				
6:30pm – 7:00pm				
7:00pm – 7:30pm	Icebreaker social		Games Night	
7:30pm – 8:00pm				
8:00pm – 8:30pm				
8:30pm – 9:00pm				

Keynote Lectures – Abstracts

Pandemic emergence: will the next pandemic be avian influenza?

Dr. Lindi Wahl
Department of Applied Mathematics
Western University
http://publish.uwo.ca/~lwahl/

Outbreaks of highly pathogenic strains of avian influenza (HPAI) cause high mortality in avian populations worldwide. When spread from avian reservoirs to humans, AI infections are extremely dangerous, with mortality in about 50% of human infections. Cases of human-to-human transmission of HPAI are rare, and have, to date, only been reported in situations of close contact (eg. mother-child care-giving). Although aerosol transmission of HPAI between humans has not yet been observed, data are limited and the possibility that aerosol transmission could already occur, at low rates, cannot be ruled out. In addition, aerosol transmission in an animal model has been observed for strains of HPAI that are genetically very similar to circulating strains. Working with a team of international students, we have estimated the highest transmission probability for aerosol human-to-human transmission of HPAI that is consistent with observed data. We predict the likelihood of observing such an aerosol transmission over the next decade in the absence of mutation, and then predict the likelihood that, through rare mutations, pandemic HPAI will emerge over the same time span.

Nobody Solves the Quintic

Dr. Dror Bar-Natan
Department of Mathematics
University of Toronto
https://www.math.toronto.edu/~drorbn/

Prerequisites:

1. The first week of any class on group theory.
2. Knowing that every complex number other than 0 has exactly n roots of order n, and how to compute them.

Everybody knows that nobody can solve the quintic. Indeed this insolubility is a well known hard theorem, the high point of a full-semester course on Galois theory, often taken in one's 3rd or 4th year of university mathematics. I'm not sure why so few know that the same theorem can be proven in about 15 minutes using *very* basic and easily understandable topology, accessible to practically anyone.

Please note that further materials for this talk are available on the talk's webpage, http://drorbn.net/cumc20. It is highly recommended to print out the handout from the webpage prior to the talk.

The Mathematics of Mathematical Handwriting Recognition

Dr. Stephen Watt
David R. Cheriton School of Computer Science
University of Waterloo
https://cs.uwaterloo.ca/~smwatt/

With the increased popularity of digital tablets, smart phones and whiteboards, it is attractive to enter and manipulate mathematical expressions using a pen, rather than a computer keyboard. Mathematical handwriting is quite different, however, than other recognition problems. Characters come from many different alphabets, are usually made up of a small number of strokes and there is no fixed dictionary of mathematical "words" to rank choices. Many symbols are quite similar, differing only in some subtleties in individual strokes.

This talk presents the approach we have taken to deal with these challenges. We show how mathematical symbols may be represented using orthogonal series related to coordinate functions and their derivatives. The handwritten symbols are then points in a low-dimensional vector space with many useful geometric properties. The geometry of the vector space leads to a natural confidence measure allowing recognition results for individual symbols to be ranked using n-gram statistics derived from empirical data. Recognition can be achieved in real time using simple device-independent numerical methods. We show how these methods allow browser-based implementation and open the door to natural on-line mathematical collaboration.

Homotopy theory: beyond topological spaces

Dr. Chris Kapulkin
Department of Mathematics
Western University
https://www.math.uwo.ca/faculty/kapulkin/

I will show how the language of category theory can be used to transfer intuitions and techniques of homotopy theory, originally an area of topology, to other areas of mathematics, including graph theory and algebraic geometry. No familiarity with pretty much anything will be assumed, but willingness to transcend the boundaries of mathematical disciplines will be required.

The integer shadows of curves

Dr. Katherine Stange
Department of Mathematics
University of Colorado, Boulder
https://math.katestange.net/

We'll take a little tour of some famous and less famous integer recurrence sequences, including the Fibonacci numbers and elliptic divisibility sequences, viewing them as shadows of geometric group laws on curves, which connects these sequences to current topics in research. Along the way, we'll use software to visually explore some of their properties.

Information geometry: geometric methods in probability and statistics

Dr. Ting-Kam Leonard Wong
Department of Statistical Sciences
University of Toronto
http://www.utstat.utoronto.ca/leonard/

A normal distribution on the real line is specified by two parameters, namely its mean and standard deviation. The collection of all normal distributions can then be regarded as a "surface" which is diffeomorphic to the upper half space; it is an example of a statistical manifold. Information geometry studies the properties of statistical manifolds and their uses in probability, statistics and machine learning. In this talk I give an introduction to the field and explain some key concepts such as Kullback-Leibler divergence (relative entropy), Fisher information metric and information projection. Explicit examples will be given to illustrate their uses. Finally I will describe how information geometry relates to optimal transport, a topic of recent research interest.

New math for old problems

Dr. Graham Denham
Department of Mathematics
Western University
http://gdenham.math.uwo.ca/

An (idealized) map is a dissection of the plane into contiguous regions ("countries"). The famous Four Colour Conjecture stated that, for any map, the countries can each be coloured in such a way that adjacent countries have different colours, provided that one is allowed to use at least four colours.

George Birkhoff's approach to this problem 100 years ago was first to take a step back: more generally, he considered graphs (rather than maps). He tried to count, for each graph, the number of colourings, using $k \geq 1$ colours, for which adjacent vertices are different colours. Remarkably, for a fixed graph G, the number of colourings turns out to be a polynomial function in k, called the chromatic polynomial of the graph.

The Four Colour Conjecture was proven in 1976, using a different approach. However, the chromatic polynomial and its generalizations have turned out to be of huge importance. I will describe some of its many remarkable properties, and indicate how modern methods have recently answered some difficult old questions about what chromatic polynomials can look like.

Mathematics Used In My Career

Dr. Carlo Lisi
Senior Manager, Analytics and Insights
TD Bank
https://ca.linkedin.com/public-profile/in/carlo-lisi-08150a/

Academia Session – Abstract

The definition of a mathematician

Dr. Rosalie Bélanger-Rioux
Department of Mathematics and Statistics
McGill University
https://www.mcgill.ca/mathstat/rosalie-belanger-rioux

In this interactive workshop, participants will reflect on what we think it means to be a mathematician, who is seen or counted as a mathematician, what causes this, and how that affects our communities of learning, teaching and research in mathematics. If you would like to explore those issues, come and find out! Be prepared to discuss some potentially difficult topics.

The webpage for this talk is https://rosaliebr.thescholr.com/presentations/interactive-workshop-definition-mathematician/.

Industry Panel – Speakers

Chris D'Onofrio

Quantitative Trading Intern at RBC Capital Markets
MSFE Candidate at Columbia University
https://www.linkedin.com/in/chris-d-onofrio-b3351211b/

Jim Wen

Software Engineer at Lyft
https://www.linkedin.com/in/jimwen1990/

William Williams

Software Engineer at Lyft
https://www.linkedin.com/in/williamwilliams/

Student Talks – Schedule

*** All times are in Eastern Daylight Time (EDT). ***

THURSDAY, AUGUST 20TH

<table>
<tr><th></th><th>Room 1</th><th>Room 2</th></tr>
<tr><td>11:00am – 11:30am</td><td rowspan="2">Laplacian Quantum Fractional Revival On Graphs

Bobae Johnson,
August Liu,
Malena Schmidt,
Neo Yin</td><td>A simulation study of some new tests of independence for ordinal data

Garima Sharma</td></tr>
<tr><td>11:30am – 12:00pm</td><td>Simulating the Geometry of Crystal Growth

Max Sun</td></tr>
<tr><td>12:00pm – 12:30pm</td><td>A Medley of Results Regarding Acyclic Polynomials of Graphs

Caroline Barton</td><td>Formal Verification of Mathematics

Daniel Carranza</td></tr>
<tr><td>12:30pm – 1:00pm</td><td>The Minimum Width Quantum Circuit For a Given Phase Polynomial

Owen Bennett-Gibbs</td><td>What information theory can tell us about language

Laurestine Bradford</td></tr>
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FRIDAY, AUGUST 21ST

	Room 1	**Room 2**	**Room 3**
11:00am – 11:30am	All the Triangles *Alex Karapetyan*	A New Approach to Solve Broken Stick Problems *William Verreault*	Sum of the Squares *Boyuan Pang*
11:30am – 12:00pm	Continued Fractions: How to understand self similar and infinite processes *Maninder Dhanauta*	Estimating underreporting of COVID-19 cases using fatality data *Margaret Hopkins*	
12:00pm – 12:30pm	Integral equation methods for the numerical solution of PDEs *Zewen Shen*	An Introduction to Algebraic Topology *Matthew How*	
12:30pm – 1:00pm	An Introduction to Geometric Group Theory *Kunal Chawla*	Chomp on Partially Ordered Sets: A Focused Introduction to Combinatorial Game Theory *Alexander Clow*	

Saturday, August 22nd

	Room 1	**Room 2**
11:00am – 11:30am	What Is The Structure Of Random Graphs At Finite Scales? *Jacqueline Doan*	Hypersets and the creativity of mathematics *Martin Shoosterman*
11:30am – 12:00pm	A Magic Trick Using the SET Deck *Zhengyu Li*	Cross-frequency coupling studies of intracranial EEG data of epilepsy patients using time-frequency distributions *Daniel Girvitz*
12:00pm – 12:30pm	Testing Mathematical Models Against Diabetes: Glucose Level Analysis *Ruo Ning Qiu, Guangya Wan, Xiaoli Yang*	An Exploration of Structural Attacks on the McEliece Public-Key Cryptosystem *Filip Stojanovic*
12:30pm – 1:00pm	The Research on the Magic Hexagon and Integer Partitions *Yun-chi Tang*	Combinatorics of Symmetric Group Representation *Curtis Wilson*

Sunday, August 23rd

	Room 1	**Room 2**
11:00am – 11:30am	Fractions with a Twist: Some applications of continued fractions *Kieran Bhaskara*	A Primer on Domain Colouring *Yuveshen Mooroogen*
11:30am – 12:00pm	Clifford gates and Shor's algorithm *Aeriana Narbonne*	Prime Numbers Modulo 4 *Ismael El Yassini*
12:00pm – 12:30pm	Women in Mathematics: A Historical Case Study of the University of Cambridge *Annie Collins*	
12:30pm – 1:00pm	Application of Sinkhorn's algorithm to tensor decompositions *Tommi Muller*	Using Differential Topology to Find a Windless Spot on Earth *Luis Carlos Soldevilla Estrada*

3:00pm – 3:30pm	An Introduction to the Fourier Transform *Amar Venga*	An Introduction to Zero Forcing *Johnna Parenteau*
3:30pm – 4:00pm	Bifurcations of an elastic ring with interacting particles *Hy Dang, Luis Mantilla, Sophia Zhang*	How to turn a needle in small areas *Uttara Sheila Rajagopalan*

Student Talks – Abstracts

Laplacian Quantum Fractional Revival On Graphs

Bobae Johnson, August Liu, Malena Schmidt, Neo Yin
Harvard University, University of Cambridge, University of Warwick, University of Toronto

Given a set of quantum bits, we can model their interactions using graphs. The continuous-time quantum walks on a graph can be viewed as the Schrödinger dynamics of a particle hopping between adjacent vertices. In this talk, the transition matrix of the continuous-time quantum walk is given by e^{-itL}, where L is the graph's Laplacian matrix.

We study the phenomenon of *fractional revival* (LaFR), useful in generating entanglement between two quantum bits. In particular, we characterize LaFR using spectral properties of the graph and present an infinite family of examples. We then prove the non-existence of LaFR on trees. Finally, we proceed to study an approximate version of LaFR called *pretty good fractional revival* on special families of trees.

This is joint work under the Fields Institute Undergraduate Summer Research Program 2020.

We are deeply grateful to the generous guidance and empowering mentorship of our supervisors Prof. Ada Chan and Harmony Zhan.

A simulation study of some new tests of independence for ordinal data

Garima Sharma
University of the Fraser Valley, Abbotsford

In a contingency table, the standard test for independence among variables is the Pearson's Chi-squared test. When the variable(s) are ordinal, for example, like scale survey data, the Chi-squared statistic does not take into account the natural orderings of the variables. In recent years, there have been several new tests proposed for ordinal data. See Lang and Ianian (2012) and Sun (2020) for a list of the tests. In this project, we examine the powers of these tests when data are generated from different dependent structures through a simulation study. Our results suggest that, in general, we should use omnibus tests due to their consistent type I error rate. The study shows that the tests proposed by Sun (2020) give good overall power. Some examples from recently literature are used to illustrate the tests.

Simulating the Geometry of Crystal Growth

Max Sun
Ontario Tech University

Prerequisites: Density functions from statistics

Past experiments on the crystallization of CO_2 in C_2H_2 fail to be adequately simulated by the classical Avarami equations. We will simulate the formation of the crystal cells using a Voroni diagram defined by randomly generated crystallization seeds (nuclei).

A Medley of Results Regarding Acyclic Polynomials of Graphs

Caroline Barton
Dalhousie University

An acyclic subset of a graph G with vertex set $V(G)$ is a subset of $V(G)$ that contains no cycles. We call the generating function for the number of acyclic subsets of each cardinality i the *acyclic polynomial* of G. We will investigate acyclic polynomials of low and high degree and investigate how the complex roots behave. Are they always in the left half-plane? Can they have arbitrarily large modulus? Can the limits of roots for families of such polynomials coalesce into curves? We will talk about all of these interesting problems and more.

Formal Verification of Mathematics

Daniel Carranza
Western University

A formal proof is a proof that has been checked by a piece of computer software, called a proof assistant, down to the very first axioms of mathematics. This talk is intended as an introduction to formal proofs and will include using a proof assistant to verify that all natural numbers are either even or odd. We will then compare this formal proof to an informal argument that can be found in mathematical textbooks.

The Minimum Width Quantum Circuit For a Given Phase Polynomial

Owen Bennett-Gibbs
Dalhousie University

The standard way to mathematically model quantum computation is unitary evolution of vectors. For a register of n qubits, the state of this register is given by a vector in a complex Hilbert space of dimension 2^n, and a quantum circuit corresponds to a unitary matrix acting on this space. Another way to represent a quantum circuit is as a *sum over paths* which vary in their phase according to a *phase polynomial*. In this talk, I will further explain these models and discuss the following problem: Given a phase polynomial, how many qubits are required to implement a circuit with this phase polynomial?

What information theory can tell us about language

Laurestine Bradford
University of Toronto

What do human languages all have in common? In terms of sound, almost every spoken language draws on the same set of possible articulations. In terms of structure, almost every language has sentences consisting of a subject, a verb, and an object. But what about meaning? The study of semantics is notoriously slippery and complicated. However, we can gain insight by studying not *what* a sentence says, but *how much* it says. In this talk, I will explain how the concept of Shannon entropy allows us to quantify the amount of information contained in a sentence. Then, I will discuss the information density of a few human languages, as measured by (Coupe et al, 2019), and indicate how this might give us a linguistic universal.

All the Triangles

Alex Karapetyan
University of Toronto

Prerequisites: A friendship with the basic ideas of groups and topological spaces.

The problem of classification is ubiquitous in mathematics, and in particular classification of geometric objects is a deep subject. This talk will be an excursion into some aspects of moduli spaces, wherein one constructs a collection of geometric objects of a fixed type as a geometric "parameter space" itself. I will explain the basic ideas using the example of triangles in the plane – how to understand the space of all triangles, what it can do, and what it cannot do. Along the way, I will describe the notion of a parametrized family of triangles, its symmetries, and how one can glue families together. The story will culminate at an important problem for moduli spaces – the failure to have a "universal family" due to the presence of automorphisms. At the end, I will outline how this problem can be resolved and how these ideas arise in nature.

A New Approach to Solve Broken Stick Problems

William Verreault
Université Laval

Prerequisites: None

Break a stick at random at $n-1$ points to obtain n pieces. We give an explicit formula for the probability that every choice of k segments from this broken stick can form a k-gon, generalizing similar work. The method we use can be applied to other geometric probability problems involving broken sticks, which are part of a long-standing class of recreational probability problems with several applications to real world models. Its main feature is the use of order statistics on the spacings between order statistics for the uniform distribution applied to the broken stick problems. We also present a discrete approach that can shed light on currently out of reach problems.

Sum of the Squares

Boyuan Pang
University of Victoria

Everyone knows what is a square, but not everyone really knows what to take out of a square. In this talk, I will debrief the unit square and its three-dimensional analog, the unit cube, with tools from algebra. Then we will splash in some analysis and topology and turn our square friend inside-out. Finally, let's welcome its complex relative who's all-round in the space...

Continued Fractions: How to understand self similar and infinite processes

Maninder Dhanauta
University of Toronto

Take the most dreaded math chapter from middle school and combine it with high school's least understood concept. The infinite continued fraction is the result of placing fractions within fractions indefinitely. These fractions make appearances in math contests to highlight tricks for manipulating self-similar, infinite processes. However, these tricks make problematic assumptions that can lead to paradoxes. This talk will use continued fractions to highlight the non-intuitive nature of self-similar, infinite processes. A motivated method to approach these processes is provided. The talk includes recursive definitions of these processes and epsilon-delta style proofs. The talk ends by introducing continued fractions as an analytical theory and some interesting theorems are also discussed.

Estimating underreporting of COVID-19 cases using fatality data

Margaret Hopkins
Acadia University

This talk investigates an important challenge facing researchers during the current COVID-19 pandemic: the lack of reliable case incidence data. Testing and reporting policies vary across regions, and in most regions it is acknowledged that the reported numbers of COVID-19 cases do not reflect the true incidence of the disease. In this talk, a model is introduced that uses death data and estimates of the infection fatality ratio (IFR) to produce estimates for the true number of COVID-19 cases in various regions. If time permits, the talk will also include discussion of a second model to improve regional estimates of the IFR using a modified SIR model and the final size relation, which is used in turn to improve the cumulative case estimates.

Integral equation methods for the numerical solution of PDEs

Zewen Shen
University of Toronto

Prerequisites: Basic numerical analysis (suggested)

Many partial differential equations (PDEs) arising from physics can be reformulated as integral equations defined on the boundary of the original problem domain. Such formulation leads to both a more benign mathematical object and a reduction of dimensionality, which enables us to derive accurate, stable and fast numerical methods for solving PDEs. This talk will provide an accessible introduction to numerical solutions of PDEs with an emphasis on integral equation methods. Integral equation formulations of PDEs, discretization of integral equations and fast algorithms for solving the resulting linear systems will be discussed.

An Introduction to Algebraic Topology

Matthew How
McMaster University

Prerequisites: Basic understanding of groups and isomorphisms. Some understanding of topology and Euler characteristic ($V - E + F$) is helpful, but not necessary.

One of the longest unsolved problems in topology is that of the universal invariant, that is, a formula for determining whether two objects in Euclidean space are 'similar' or 'different'. Euler began this line of work back in the 1750's when it was found that "similar" objects had the same Euler characteristic. However, it can easily be seen that this invariant has its shortcomings. In the 20th century, mathematicians found that the tools of algebra could be applied in a natural way to this problem, leading to the creation of several powerful new invariants: homotopy, homology and cohomology. This talk will give an exposition of the first major result of algebraic topology, that the fundamental group of the circle is isomorphic to the additive group of integers. The construction is strikingly natural, and provides a glimpse of the beautiful connection between two seemingly different fields of mathematics.

An Introduction to Geometric Group Theory

Kunal Chawla
University of Toronto

Prerequisites: Basic group theory

Geometric Group Theory is an exciting and relatively new field which seeks to understand spaces by their symmetries, and symmetries as spaces. It has strong connections to low-dimensional topology, complexity theory, and algebraic topology (and is the source of many nice pictures!). In this talk we'll give a short introduction to the main ideas of the field, as well as some nice results.

Chomp on Partially Ordered Sets: A Focused Introduction to Combinatorial Game Theory

Alexander Clow
St. Francis Xavier University

This talk aims to introduce Combinatorial Game Theory by focusing on impartial games, particularly Poset Chomp. It will introduce some of the basic theorems of Combinatorial Game Theory such as Zermelo's theorem, the Sprague–Grundy theorem and how to sum disjoint impartial games. The talk does not expect prior knowledge of the above, but for those who are interested, *Winning Ways for your Mathematical Plays* by Berlekamp, Conway and Guy provides a rigorous basis. The talk will conclude by covering a novel but accessible result in Poset Chomp, which greatly generalizes HackenBush's Colon Principle to Poset Chomp.

What Is The Structure Of Random Graphs At Finite Scales?

Jacqueline Doan
Western University

Random graphs provide important models for a range of social, technological, and biological systems. The structure of these graphs is represented by an adjacency matrix A, where $A_{ij} = 1$ whenever node i and j are connected, and $A_{ij} = 0$ otherwise. The eigenvalues of these matrices are important in determining the behaviors of networked systems, from the transition to chaos in random neural networks, to epidemic thresholds for infections propagating through human populations. While the distribution of the eigenvalues of random $N \times N$ matrices as $N \to \infty$ is well understood, not much is known about the eigenvalues of random $N \times N$ matrices at finite scale. This talk offers an introduction to networks, regular graphs, random graphs, and their eigenspectra. We will then investigate the connections between regular graphs and random graphs via patterned edge removal. When viewed in a sequential manner, the effects of systematic edge removal exhibit surprising regularity. At the end of this talk, we will discuss prospects for our future research work.

Hypersets and the creativity of mathematics

Martin Shoosterman

University of Toronto

Prerequisites: Basic understanding of Naive set theory

In this talk we will examine how mathematics allows for creativity by showing how a new area of mathematics can be created by making changes to an existing structure. We will explore this by looking at axiomatic set theory and exploring how we can change the axioms to allow for the existence of a new type of set which is called a hyperset. We will then consider some questions which pop up when working with hypersets and look at attempts to answer those questions using some graph theory.

This talk will assume almost no prior knowledge of axiomatic set theory, and no prior knowledge at all of graph theory.

A Magic Trick Using the SET Deck

Zhengyu Li

University of Toronto, Mississauga

Prerequisites: None

What's more magical than mathematics? Mathemagic, of course. Our trick "In TetraCycles" is a variation on the "In Cycles" trick developed by Persi Diaconis and Ron Graham. Four volunteers draw four consecutive SET cards from the 81-card deck. Then the magician can easily predict all four cards, only given information of one random feature. How is such a trick possible? Turns out that the magic of combinatorics, graphs, and sequences are behind this trick and making it happen. The talk will extensively discuss a special type of sequence that is used in “In TetraCycles” and how it connects to graph theory and combinatorics. We will also provide a walkthrough of the trick so that anyone can perform the trick with some practice! We dedicate this work to the memory and legacy of Dr. Ronald Graham.

Cross-frequency coupling studies of intracranial EEG data of epilepsy patients using time-frequency distributions

Daniel Girvitz
University of Calgary

In this presentation, I address the question on the relevance of time-frequency distributions (TFD) for cross-frequency coupling studies, an area of interest in computational neuroscience. Cross-frequency coupling (CFC) is defined to be a phenomenon of a lower frequency band of neuronal signals from one region of the brain modulating higher frequency bands of the same region or other brain regions. This is suggested to be one of the key mechanisms to understand information processing in brains. Here, I study human epilepsy by analyzing and interpreting intracranial electrical encephalogram (iEEG) data recorded on or inside the brain. The iEEG data are intrinsically non-stationary. Traditional Fourier transform methods offer non-localized and poorly resolved information on simultaneous occurrences of events in time and frequency. To resolve this, I adapt time-frequency distributions to study cross-frequency coupling and in particular, phase-amplitude coupling (PAC). In this presentation, I show with a couple of examples of time-frequency distributions, reduced interference Rihaczek TFD and Stankovic’s transform methods and how the phase and amplitude are extracted and the phase-amplitude coupling metrics are studied with human epilepsy data.

Testing Mathematical Models Against Diabetes: Glucose Level Analysis

Ruo Ning Qiu, Guangya Wan, Xiaoli Yang
University of Toronto

Prerequisites: Basic Statistics

In the hope to develop personalized medicine, we want to construct a rule and regulation process of glucose level against diabetes and characterize glucose level of individuals. Does glucose level always increase after eating food and stay stable without food intake? Would you gain the same time trace curves if you fix your schedule of eating/drinking, exercising, and sleeping? What can we learn from the time traces in general? In this talk, we will answer these questions and explain how we handle and perform the quantitative analysis on the raw time-series data with short time intervals collected from a newly developed continuous monitoring glucose device, commenting on the reproducible patterns of the time traces. A physiological model of differential equations supported by literature will be presented with a brief introduction to parameter sensitivity as the model parameters cannot be reliably inferred.

An Exploration of Structural Attacks on the McEliece Public-Key Cryptosystem

Filip Stojanovic
University of Ottawa

The threat of quantum computers on the public-key cryptosystems (PKCs) currently used to ensure our online privacy is well understood. It is in opposition to this threat that the National Institute of Standards and Technology (NIST) launched its initiative to find classically-secure and quantum-resistant PKCs, which, given that NIST has recently announced its finalists, now demands closer scrutiny of its lead contenders than ever before. Among the finalists is the McEliece PKC based on binary Goppa codes, a cryptosystem based on linear error-correcting codes.

In this talk, we briefly introduce the theory of error-correcting codes so as to describe the McEliece PKC and one of two major classes of classical attacks against it. We define Goppa codes and the more familiar family of Generalized Reed Solomon (GRS) codes and briefly describe their relationship. We present a polynomial-complexity attack that decrypts the ciphers of a McEliece scheme based on GRS codes instead of Goppa codes. We identify a special case in which the same attack that's successful against the McEliece PKC based GRS codes is also successful against the McEliece scheme based on Goppa codes.

The Research on the Magic Hexagon and Integer Partitions

Yun-chi Tang
University of Toronto

Prerequisites: Elementary Number Theory might be a plus, but the presentation can be understood without it.

It turns out that when we modify the 3 by 3 magic square and turn it into a magic hexagon of side length 3, there still exist just exactly one possible solution with numbers from 1 to 19. Unlike in the case of the magic square, however, proving why there exists one unique solution does not appear to be straight forward; the previous proof involved using a Honeywell-8000 computer that is the size of multiple rooms! In this talk, we will use integer partitions and various other pieces of information to avoid the cumbersome calculations required to show the uniqueness of the magic hexagon.

Combinatorics of Symmetric Group Representation

Curtis Wilson
Queen's University

The symmetric group $\mathfrak{S}_n$ is the set of permutations of n equipped with composition of functions. We demonstrate how to represent this group in terms of matrices followed by their decomposition. We then introduce a combinatorial object for partitions, the Young diagram, which will provide us with a way to determine a representation's decomposition. We end with a bijection between a certain subset of the Young diagrams and the elements of $\mathfrak{S}_n$.

Fractions with a Twist: Some applications of continued fractions

Kieran Bhaskara
Dalhousie University

Continued fractions are a central part of mathematics, frequently arising in many areas of number theory and analysis. In this talk, I give a general introduction to continued fractions and their use in solving several types of number-theoretic problems. No previous knowledge of continued fractions is required.

A Primer on Domain Colouring

Yuveshen Mooroogen
University of Toronto

Prerequisites: A first course of linear algebra. You should be comfortable with the concept of dimension. Familiarity with the complex numbers will be useful, although I will review necessary ideas very briefly. Knowledge of multivariable calculus and complex analysis is NOT expected.

In this talk, I will explain how to read a domain colouring, which is a technique used to illustrate functions of the complex numbers. I will begin with a review of why such functions are difficult to draw. Next, I will present a recipe for constructing domain colourings, focusing on a number of simple examples. Towards the tail end of the presentation, I will take you on a stroll through a little zoo of complex functions, and comment on the theorems to which they relate.

Clifford gates and Shor's algorithm

Aeriana Narbonne
University of King's College

Quantum computation has become a topic of great interest since Shor's algorithm to factor numbers in polynomial time. However, to date there is no efficient method to simulate quantum circuits on classical computers. Gottesman–Knill theorem states that a quantum circuit which uses Clifford gates can be simulated in polynomial time on a classical computer. I will present an overview of Clifford gates, how we might go about simulating these circuits on classical computers, which would allow us to use Shor's algorithm.

Prime Numbers Modulo 4

Ismael El Yassini
University of Sherbrooke

Prerequisites:

- Operations of addition and multiplication modulo n
- Little Fermat Theorem: for p a prime number and a and p coprime, then p divides $a^{p-1} - 1$

Several results in Number Theory will be presented especially about prime numbers modulo 4. We will use a very strong application of the pigeonhole principle in number theory to prove Fermat Theorem: every prime number of the form $4k + 1$ can be written as the sum of two squares.

Women in Mathematics: A Historical Case Study of the University of Cambridge

Annie Collins
University of Toronto

In the modern age, the faculty of mathematics at the University of Cambridge ranks amongst the top in the world and has produced some of the greatest minds in the field's history. One aspect of mathematics education that distinguishes Cambridge from other universities is its famed Mathematical Tripos examination. Another distinguishing factor is how the culture and policies of the University have historically hindered women's participation and success in mathematics. This talk tells the story of women's struggles while studying

mathematics at the University of Cambridge in the 19th century. It examines the role that the Mathematical Tripos specifically has played in women's ability to succeed and the way that the broader University environment has influenced women's participation in mathematics throughout history and even to this day.

Application of Sinkhorn's algorithm to tensor decompositions

Tommi Muller
University of British Columbia

Tensors are multidimensional arrays of numbers, generalizing scalars, vectors, and matrices. Decomposing tensors have a wide range of applications, from statistics to quantum mechanics. Tensors can be very complex objects, however they can be graphically represented in a simple manner called tensor networks. We investigate the decomposition of a particular tensor network called a tensor train, and we show how Sinkhorn's algorithm can be used to solve such problems. Sinkhorn's algorithm is a matrix-scaling algorithm that has recently seen frequent application in solving optimal transport theory problems, and hence we see its interesting use in this unique context.

Using Differential Topology to Find a Windless Spot on Earth

Luis Carlos Soldevilla Estrada
University of Toronto

If we consider the earth as a 2-D sphere, does there exist a point where no wind is blowing ? One of the many answers to this question can be found as a theorem of Algebraic Topology. In this talk I will present a proof of this result using techniques from Differential Topology. I will begin by introducing the audience to the theory of manifolds and presenting some important characteristics of these structures, such as transversality and the euler characteristic. This introductory material will be used to present the Poincare-Hopf Theorem, which will lead to the answer of the initial question.

An Introduction to the Fourier Transform

Amar Venga
Western University

Prerequisites: Real analysis, a bit of linear algebra, and a bit of topology

We examine the Fourier transform from the perspective of distribution theory. First, we recall some important concepts from real analysis, including convolutions and distributions;

and some key results, such as Fubini's Theorem and the Dominated Convergence Theorem. We then define the Fourier transform and the inverse Fourier transform, and establish some early but important results, including the Fourier Inversion Theorem and the Convolution Theorem. Finally, we give some key examples of Fourier transforms, and discuss its many uses.

An Introduction to Zero Forcing

Johnna Parenteau
University of Regina

Zero forcing is a combinatorial game played on a graph G where the goal is to fill the unfilled vertices of a graph at minimal cost, denoted as $Z(G)$, using two specified actions: (1) at any point, a vertex can be filled for a cost of one token, and (2) at no cost, the player can apply the filling rule. In this presentation, I will introduce the Z-Game and a closely related variation known as the q-analogue of zero forcing (or simply the Z_q-Game), and I will discuss its motivation in relation to the minimum rank problem and present some relevant and interesting results developed in recent years.

Bifurcations of an elastic ring with interacting particles

Hy Dang, Luis Mantilla, Sophia Zhang
Texas Christian University, Universidad de los Andes

Many-body systems appear in a diverse range of fields, such as microbiology, condensed matter physics, and chemistry. While some many-body systems only involve interactions between the bodies themselves, other systems involve interactions between both the bodies and the space on which they are constrained. In this talk, we will focus on a canonical example of such a system – N interacting particles constrained to a deformable elastic ring. Using methods from optimal control theory, we derive conditions that the particle-ring system must satisfy to be in static equilibrium. We then consider the bifurcations that can occur as the interaction strength between the particles increases. Particular focus is given to the case of two and three particles. From these results, we are able to propose a general structure of the bifurcation behavior for $N > 3$ particles. Specifically, as the interaction strength increases, the N particles can bifurcate to form $M \leq N$ clusters, which then behave similarly to the case of M individual particles.

How to turn a needle in small areas

Uttara Sheila Rajagopalan
University of Toronto

Prerequisites: First year calculus – formal epsilon-delta definitions of limits and continuity, familiarity with summation notation and the ideas behind Riemann integration

In 1917, Soichi Kakeya posed the following problem:

> Which is the figure of least area in which a line segment of length 1 (a needle) can be continuously turned through 360°?

In 1928, Abram Besicovitch proved the surprising result that there is no minimal figure. In this talk, I will discuss a simplified version of his solution to the Kakeya needle problem by constructing a figure with arbitrarily small area out of overlapping triangles.