HMMT February Education Events

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Education Events | **February 20, 2022**

Time (EST)	Education Room 1	Education Room 2	Education Room 3
11:00 AM - 12:00 PM	**Michael Sipser** *Beyond Computation: What Are the Theoretical Limitations of Computer Power?*	**Dora Woodruff** *Ultrafilters and Voting Theory*	
1:00 PM - 2:00 PM	**Tamara Broderick** *Nomon: A Single-Switch Interface for Assistive Technology*	**Wes Cain** *Tic-Tac-Toe*	**Sanjay Raman** *Quantum Field Theory: A Mathematical Perspective*
2:00 PM - 3:00 PM	**Scott Sheffield** *Random-turn Game Theory*	**Hari Iyer** *Beyond the Riemann Zeta Function*	**Gaurav Goel** *The Three-Sphere and Dante's Divine Comedy*

3:30 PM - 4:30 PM	**Po-Shen Loh** **Professor, Carnegie Mellon University** **USA IMO Coach** **Applied Math** Education Room 1	***Applied Math: A new solution to beyond-curriculum math inspiration at scale, while helping high school math stars build magnetic communication skills*** *Po-Shen Loh is a mathematician who enjoys people. That background fuels his work as a serial innovator and social entrepreneur, where he uses math to discover fundamentally new approaches to address major societal issues. In this talk, Prof. Loh will discuss some of this recent work, from the perspective of a mathematician who enjoys people.*

February Education Events

Time: 11:00 AM - 12:00 PM

Michael Sipser

Beyond Computation: What Are the Theoretical Limitations of Computer Power?

11:00 AM - 12:00 PM | Education Room 1

In a remarkable 1956 letter, the great logician Kurt Gödel asked the famous mathematician and computer pioneer John von Neumann whether certain computational problems could be solved without resorting to brute force search. In doing so, he foreshadowed the P versus NP question, one of the major unanswered questions of contemporary mathematics and theoretical computer science.

Michael Sipser is the Donner Professor of Mathematics and member of the Computer Science and Artificial Intelligence Laboratory at MIT. He received his PhD from UC Berkeley in 1980 and joined the MIT faculty that same year. He was Chairman of Applied Mathematics from 1998 to 2000 and served as Head of the Mathematics Department 2004-2014. He served as interim Dean of Science 2013-2014 and then as Dean of Science 2014-2020. His research areas are in algorithms and complexity theory, specifically efficient error correcting codes, interactive proof systems, randomness, quantum computation, and establishing the inherent computational difficulty of problems. He is the author of the widely used textbook, Introduction to the Theory of Computation (Third Edition, Cengage, 2012).

Technicality/Prerequisites: None.

Dora Woodruff

Ultrafilters and Voting Theory

11:00 AM - 12:00 PM | Education Room 2

Set theory is such an abstract area of math, and economics is at the applied end of math, so economists such as Kenneth Arrow and set theorists of the mid-1900s were surprised to discover that they were secretly working with the same construction, on similar problems. The idea of ultrafilters from set theory and the problems of voting theory posed by 1900s economists come together to prove a beautiful but philosophically disturbing result known as Arrow's Theorem. In this talk, we will sketch a proof of the theorem, with some meanders through set theory along the way. Little to no prerequisite knowledge is assumed.

Dora Woodruff is a sophomore at Harvard University concentrating in mathematics. Along with an interest, dating back to high school contests, and research experience in combinatorics and graph theory, she loves thinking about logic and set theory. She also loves playing the oboe, reading, and birdwatching in her spare time.

Technicality/Prerequisites: None.

Time: 1:00 - 2:00 PM

Tamara Broderick

Nomon: A Single-Switch Interface for Assistive Technology

1:00 - 2:00 PM | Education Room 1

Nomon is our open-source software designed to allow single-switch communication, drawing, gaming, and other GUI usage for individuals with severe motor impairments (e.g. patients with cerebral palsy, locked-in syndrome, etc). Nomon uses Bayesian machine learning and modified kernel density estimation to adapt automatically to an individual's switch activation ("clicking") ability. In particular, Nomon (automatically) allows a person who clicks precisely to make a selection quickly and allows a person who clicks imprecisely more time to make a selection without error. Initial user studies demonstrate the usefulness of Nomon in practice. We are currently working on longer-time-scale user studies in both able-bodied and motor-impaired populations to better understand the performance of Nomon.

Tamara Broderick is an Associate Professor in the Department of Electrical Engineering and Computer Science at MIT. She is a member of the MIT Laboratory for Information and Decision Systems (LIDS), the MIT Statistics and Data Science Center, and the Institute for Data, Systems, and Society (IDSS). She completed her Ph.D. in Statistics at the University of California, Berkeley in 2014.

Her recent research has focused on developing and analyzing models for scalable Bayesian machine learning. She has been awarded selection to the COPSS Leadership Academy (2021), an Early Career Grant (ECG) from the Office of Naval Research (2020), an AISTATS Notable Paper Award (2019), an NSF CAREER Award (2018), and a Sloan Research Fellowship (2018).

Technicality/Prerequisites: None.

Wes Cain

Tic-Tac-Toe

1:00 - 2:00 PM | Education Room 2

Most of us, at some point during childhood, learned to play the game "tic-tac-toe" (which is known by a variety of other names around the world). It may surprise you to know that tic-tac-toe is connected to some theorems of major importance in mathematics! In this talk, I will discuss some of these connections. I will also consider some variations of the usual tic-tac-toe game, along with some proofs regarding which player (if any) has a winning strategy. I will conclude by mentioning a few unresolved conjectures regarding tic-tac-toe, and some mathematical approaches that might be promising.

John Wesley Cain is a Senior Lecturer on Mathematics at Harvard University. His academic interests lie at the interface of mathematics, medicine, and biology. His past and current projects involve: cardiac electrophysiology, biochemical reaction kinetics, wound healing and the acute inflammatory response, and the emergence of de novo genes. Prior to arriving at Harvard in 2015, he spent 10 years as a mathematics professor in Virginia after completing his PhD at Duke University in 2005.

Technicality/Prerequisites: None.

Time: 1:00 - 2:00 PM

Sanjay Raman

Quantum Field Theory: A Mathematical Perspective

1:00 - 2:00 PM | Education Room 3

Picture this: You're an aspiring physicist, and you find yourself interested in attending some seminars. You start scrolling through a list of talks offered at the nearest conference, and you see something about quantum field theory. This sounds exciting to you, so you sign up. On the day of the seminar, you show up, and the speaker immediately begins by saying this:

Of course, it is clear that a quantum field theory is a monoidal functor from a category of cobordisms to a category of Hilbert spaces.

Now, if you're anything like me, it is not at all clear that this is true; in fact, it's not at all clear what any of these words mean!

However, quantum field theory is a fascinating subject, and the mathematical foundations of it are even more intricate and exciting. In this course, we will explore quantum field theory from both physical and mathematical perspectives, studying the physics that explains our universe and the relevant underlying mathematics. If time allows, we will discuss exciting new developments in the field.

Sanjay Raman is a third-year undergraduate at MIT, majoring in physics and mathematics with a minor in music. He is currently doing research in effective field theory, quantum gravity, and quantum computation.

Technicality/Prerequisites: Significant mathematical maturity required. Some knowledge of quantum mechanics is helpful but not required. Familiarity with linear algebra is essential.

Time: 2:00 - 3:00 PM

Scott Sheffield

Random-turn Game Theory

2:00 - 3:00 PM | Education Room 1

In this class, we'll hear a fun story about Professor Sheffield's research on a simple game, random-turn Hex.

From "Random-Turn Hex and other selection games": The game of Hex has two players who take turns placing stones of their respective colors on the hexagons of a rhombus-shaped hexagonal grid. Black wins by completing a crossing between two opposite edges, while White wins by completing a crossing between the other pair of opposite edges. Although ordinary Hex is famously difficult to analyze, Random-Turn Hex--in which players toss a coin before each turn to decide who gets to place the next stone--has a simple optimal strategy. It belongs to a general class of random-turn games--called selection games--in which the expected payoff when both players play the random-turn game optimally is the same as when both players play randomly. We also describe the optimal strategy and study the expected length of the game under optimal play for Random-Turn Hex and several other selection games.

Scott Sheffield is the Leighton Faculty Professor of Mathematics as of July 2017. He joined the MIT faculty as Professor in 2008, following a faculty appointment at the Courant Institute at NYU. He received a PhD in mathematics from Stanford University in 2003 under the supervision of Amir Dembo, and completed the AB and AM degrees in mathematics from Harvard in 1998. Sheffield is a probability theorist, working on geometrical questions that arise in such areas as statistical physics, game theory and metric spaces, as well as long-standing problems in percolation theory.

Technicality/Prerequisites: None.

Time: 2:00 - 3:00 PM

Hari Iyer

Beyond the Riemann Zeta Function

2:00 - 3:00 PM | Education Room 2

The Riemann hypothesis is perhaps one of the most famous unsolved problems in number theory, with significant consequences for questions of arithmetic. Though this conjecture remains out of reach, there are a number of related questions and analogies and generalizations of the zeta function, which have inspired much beautiful mathematics in the last 150 years. After discussing some background on the zeta function, we aim to explore a couple of these fruitful directions.

Hari Iyer is a sophomore from Ohio studying mathematics at Harvard College. So far, he has enjoyed studying number theory and algebraic geometry, and he hopes to pursue research in mathematics after college.

Technicality/Prerequisites: There are no strict technical prerequisites as the class may be kept fairly conceptual if desired, though depending on student interest, complex analysis may be useful.

Gaurav Goel

The Three-Sphere and Dante's Divine Comedy

2:00 - 3:00 PM | Education Room 3

Everyone knows what a circle looks like—we learnt it in grade school. We can visualize the circle easily because we can draw it in a plane. What about the surface of a sphere, or a two-sphere? Any planar drawing of a two-sphere is necessarily imperfect (at least two historic theorems prove different versions of this!), but we can still visualize it since we can picture it sitting inside the three-space we inhabit. Think of a beach ball. What about the next higher dimension? Is there a way we can visualize the hypersphere, or a three-sphere? Again, not as easily, we can the two-sphere since there is in fact no way to embed it into the three-space we inhabit, and visualizing four-dimensional space is hard. In fact, however, humans have been thinking about the three sphere for millennia (astronomers know this, and Dante's Divine Comedy can be thought of as taking place in a three-sphere as well!). In this talk, I will talk about ways we can think about the three-sphere: different ways of visualizing it, giving it coordinates, and studying its geometry. I will also mention connections with classical and quantum physics.

Gaurav Goel is an undergraduate at Harvard from India studying mathematics and music. He is a board member for Gender Inclusivity in Mathematics (GIIM) and sings with the Harvard Glee Club. His favorite author is J. R. R. Tolkein, and his current favorite hobby is reading a German translation of "The Hobbit." On a Saturday, you can find him in his room re-watching Black Mirror, or reading mathematical philosophy, or simply catching up on sleep.

Technicality/Prerequisites: High school geometry. Familiarity with solid geometry and 3D coordinate geometry will be helpful.