HMMT November Education Events

Education Events Schedule

November 13, 2022

Time (EST)	Emerson 101	Emerson 108	Emerson 305
8:45 AM - 9:30 AM	**Registration & Breakfast** Ticknor Lounge, Boylston Hall		
9:30 AM - 10:30 AM	**Mark Takken** *Spherical Trigonometry with Applications to Astronomy*	**Dora Woodruff** *Snakes on a Plane!*	**Ronitt Rubinfeld** *What Can We Do in Sublinear Time?*
10:30 AM - 11:30 AM	**John Gruber** *Health Care Reform in the 21st Century*	**Daniel Larsen** *Fourier Analysis, Primes, and Carmichael Numbers*	**Richard Allen** *Understanding the Nobel Prize: Quantum Entanglement and Bell Inequalities*
11:30 AM - 1:00 PM	**Lunch break** In Harvard Square		
1:00 PM - 2:00 PM	**Dhruv Goel** *Emmy Noether: Mathematician Extraordinaire*	**Jacob Barandes** *Representation Theory, Probability, and Quantum Mechanics*	**Sam Kou** *A Perspective on Statistics vs. Mathematics*

Time: 9:30 - 10:30 AM

Mark Takken

Special Trigonometry with Applications to Astronomy

Emerson 101

What is the altitude and direction of the Sun in the sky at this very moment? What is the time and direction of sunset today? How could we construct an accurate sundial for Cambridge, MA, at this time of year? Planar trigonometry on its own will not get us anywhere since the Earth and sky are not flat [citation needed], so instead, we will turn to the forgotten science of spherical trigonometry. We will start by developing all of the right-triangle formulas, among which we will discover a beautiful and surprising symmetry, and then extend them to the spherical equivalents of the Law of Sines and Cosines. Finally, we will use what we've learned to solve some of the above astronomical problems!

Mark Takken is a freshman at Harvard studying applied math. He is an alumnus of HCSSiM and Mathcamp, where in 2022, he taught a similar class on spherical trigonometry. Non-obscure topics that excite him include reinforcement learning and signals processing. His non-academic interests include playing Go, singing, and skiing.

Technicality/Prerequisites: Planar trigonometry.

Dora Woodruff

Snakes on a Plane!

Emerson 108

I'll discuss some interesting and famous problems in combinatorial and discrete geometry, such as the Unit Distance Problem and the Distinct Distance Problem. Hopefully, there will be time to talk about some recent developments in the field, with a note about my own research!

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: Introductory combinatorics — nothing else.

Ronitt Rubinfeld

What Can We Do in Sublinear Time?

Emerson 305

*We have long considered showing the existence of a linear time algorithm for a problem to be the gold standard of achievement. Indeed, it is hard to imagine doing any better than that, since for any nontrivial problem, any algorithm must consider all of the input in order to make a decision. However, as extremely large data sets grow more prevalent in a wide variety of settings, it is natural to wonder what one can do in *sublinear* time. Such algorithms can only view a minuscule portion of the input, yet they must return an answer that is meaningful in some way. Over the past two decades, there has been much interest in this direction and beautiful algorithms have been developed. This talk will give a few examples of such sublinear time algorithms.*

Ronitt Rubinfeld is the Edwin Sibley Webster Professor in MIT's Electrical Engineering and Computer Science department, where she has been on the faculty since 2004.

Ronitt's research centers on property testing and sub-linear time algorithms that analyze data by looking at only a very small portion of it. Her work has developed the field of sublinear time property testers and approximation algorithms for functions, combinatorial objects and distributions.

Ronitt Rubinfeld was an ONR Young Investigator, a Sloan Fellow, and an invited speaker at the International Congress of Mathematicians in 2006. She is a fellow of the ACM, a fellow of the American Academy of Arts and Sciences, and a member of the National Academy of Sciences. She received the 30 year test of time award from the STOC conference for her work with Blum and Luby on self-testing/correcting with applications to numerical problems.

Technicality/Prerequisites: Familiarity with Big O notation.

Time: 10:30 - 11:30 AM

John Gruber

Health Care Reform in the 21st Century

Emerson 101

This talk will discuss what is wrong with the single largest sector of the U.S. economy, health care. I will discuss prospects and directions for addressing the problems that exist in this sector.

Jonathan Gruber is the Ford Professor of Economics at MIT, where he has taught since 1992. He is a member of the Institute of Medicine, the American Academy of Arts and Sciences, the National Academy of Social Insurance, and the Econometric Society. He has published more than 180 research articles, has edited six research volumes, and is the author of Public Finance and Public Policy, a leading undergraduate text, Health Care Reform, a graphic novel, and Jump-Starting America: How Breakthrough Science Can Revived Economic Growth and the American Dream (with Simon Johnson). In both 2006 and 2012, he was rated as one of the top 100 most powerful people in health care in the United States by Modern Healthcare Magazine. In 2020, he received a Guggenheim Fellowship. He was also an advisor to the Obama Administration and Congress during the development of the Affordable Care Act.

Technicality/Prerequisites: None.

Daniel Larsen

Fourier Analysis, Primes, and Carmichael Numbers

Emerson 108

Suppose you flip a million coins. What is the probability of getting exactly half of the coins to come out heads? I will start by introducing a method of analyzing this problem using the method of Fourier analysis. Then I will show how this same idea can be generalized to a startling extent, showcasing several applications in number theory, among them, a proof of Bertrand's Postulate for Carmichael numbers and a glimpse into the Riemann Hypothesis. At the same time, I will demonstrate how probabilistic methods can be applied not just to make statements about odds and expected outcomes but to prove very concrete theorems.

Daniel Larsen is a freshman at MIT planning on studying math. He is specifically interested in number theory and its connections to ideas from physics. Daniel's work on Carmichael numbers has been published in the journal "International Mathematics Research Notices." In his spare time, Daniel enjoys reading, playing chamber music, and kicking around a soccer ball.

Technicality/Prerequisites: Knowledge of groups is helpful but not necessary.

Richard Allen

Understanding the Nobel Prize: Quantum Entanglement and Bell Inequalities

Emerson 305

Entanglement is so central to quantum information that Erwin Schrodinger called it "not just one but rather the characteristic trait of quantum mechanics." But what exactly is this "spooky action at a distance," and how do we know it is an inherently quantum effect? This year's Nobel Prize in Physics was awarded for a series of experiments demonstrating increasingly loophole-free violations of Bell inequalities, bounds which experimental observables would have to satisfy if the laws of nature were classically deterministic. In this talk, we will work to understand the significance of the Nobel Prize winning work and the applications of quantum entanglement.

Richard Allen is a first-year PhD student at MIT working in quantum information theory. He is interested in the kinds of condensed matter systems that can be simulated on a quantum computer, the use of quantum mechanics for precision measurement, and quantum complexity theory. In his free time he can be found hiking, rock climbing, or making ceramics. He's been a part of HMMT since his undergraduate days at Harvard.

Technicality/Prerequisites: Basic familiarity with probability will be assumed. Some experience with linear algebra / vectors would be helpful, but is not required.

Time: 1:00 - 2:00 PM

Dhruv Goel

Emmy Noether: Mathematician Extraordinaire

Emerson 101

Described by Einstein as the most important woman in the history of mathematics, German mathematician Emmy Noether (1882-1935) made fundamental contributions to the fields of group theory, algebraic invariant theory, elimination theory, noncommutative algebra, and mathematical physics. On the other hand, her brilliant but short life as a researcher and teacher was riddled with difficulties ranging from struggles against entrenched gender norms to later her expulsion from Göttingen due to the Nazi party. Inspired by a book of the same name by historian and mathematician David Rowe, this talk aims to give a summary of the story of Noether's life and mathematics.

Dhruv Goel is an undergraduate at Harvard from India studying mathematics, German, and music. Their primary academic and research interests lie in studying algebraic geometry from various perspectives, including those of complex differential geometry, enumerative and combinatorial geometry, and arithmetic geometry. They also enjoy studying computational number theory, algebraic topology, and symplectic geometry. Dhruv currently serves as co-president for Harvard Undergraduate Gender Inclusivity in Mathematics (HUGIIM) and sings with the Harvard Glee Club and the Harvard University Choir. Their favorite author is J. R. R. Tolkein, and their current favorite hobby is reading the German translations of "The Hobbit" and "The Lord of the Rings". On a Saturday, you can find them in their room re-watching Black Mirror, practicing on the viola da gamba, or catching up on sleep.

Technicality/Prerequisites: Some familiarity with polynomials will be assumed. Familiarity with group theory will be helpful but is not required.

Jacob Barandes

Representation Theory, Probability, and Quantum Mechanics

Emerson 108

After reviewing the arithmetic of matrices, this talk will provide an introduction to an important mathematical subject called representation theory, which we'll develop through its concrete applications to geometry, the complex numbers, and classical probability. We'll then be able to pinpoint where classical probability ends and quantum mechanics begins. We'll conclude by constructing the foundations of quantum mechanics from first principles.

Jacob Barandes is a Lecturer and Co-Director of Graduate Studies for the Department of Physics at Harvard, where he also did his PhD in theoretical physics. Dr. Barandes does research at the intersection of physics and philosophy. His main areas of study include the foundations of quantum mechanics, the classical limit, field theory, general relativity, thermodynamics, and formal methods in mathematical physics. He is also interested in logic, the philosophy of probability, and the philosophy of time.

Technicality/Prerequisites: Basic high-school algebra and trigonometry.

Sam Kou

A Perspective on Statistics vs Mathematics

Emerson 305

This talk will elaborate on the differences and similarities between statistics and mathematics and the different principles that underlie each, using a few examples.

Sam Kou is a Professor of Statistics in the Harvard Faculty of Arts and Sciences and Professor of Biostatistics in the Harvard T.H. Chan School of Public Health. Professor Kou's research interests include stochastic inference in single molecule biophysics, chemistry, and biology; Bayesian inference for stochastic models; nonparametric statistical methods; model selection and empirical Bayes methods; Monte Carlo methods; and economic and financial modeling.

Professor Kou is the recipient of the COPSS (Committee of Presidents of Statistical Societies) Presidents' Award; a U.S. National Science Foundation CAREER Award; the Raymond J. Carroll Young Investigator Award; the Institute of Mathematical Statistics Richard Tweedie Award; and the American Statistical Association Outstanding Statistical Application Award. Professor Kou is an elected Fellow of the American Statistical Association, an elected member of the International Statistical Institute, and a Medallion Lecturer and an elected Fellow of the Institute of Mathematical Statistics.

Technicality/Prerequisites: None.

Food Options in Harvard Square

Students will have a 1.5-hour break (from 11:30 AM to 1 PM) to eat lunch. Unlike many HMMT events, food will *not* be provided at the event. We've compiled a list of nearby lunch options for you to consider; all of these options are fast and fairly affordable. Please plan to be back at Harvard campus by 12:50 PM to ensure that you arrive at the 1 PM class on time.

Clover Food Lab - *vegetarian*
1326 Massachusetts Ave, Cambridge, MA

El Jefe's Taqueria - *burritos, tacos, bowls*
14 Brattle St, Cambridge, MA

Felipe's Taqueria - *burritos, tacos, bowls*
21 Brattle St, Cambridge, MA

Menya Jiro - *ramen*
57 John F. Kennedy St, Cambridge, MA

Pinnochio's Pizza - *pizza*
74 Winthrop St, Cambridge, MA

Saloniki Greek - *pitas, mezes, Greek Plates*
24 Dunster St, Cambridge, MA

Santouka - *ramen*
1 Bow St, Cambridge, MA

Shake Shack - *burgers*
92 Winthrop St, Cambridge, MA

Tasty Burger - *burgers*
40 John F. Kennedy St, Cambridge, MA

Veggie Grill - *vegetarian*
57 John F. Kennedy St, Cambridge, MA