HMMO November

Education Events and Panels | **November 22, 2020**

Schedule

Stream Link (for Sessions in Room 4 and Panels): link.hmmt.org/stream

Time (EST)	SESSIONS			
	Education Room 1 link.hmmt.org/ed1	**Education Room 2** link.hmmt.org/ed2	**Education Room 3** link.hmmt.org/ed3	**Education Room 4** link.hmmt.org/ed4
1:00 - 1:45 PM	**Joe Blitzstein** *The Probabilistic Method: Using Probability to Prove Existence*	**Yufei Zhao** *Equiangular Lines and Spectral Graph Theory*	**Jon Gruber** *Healthcare in the U.S.: What Happens Now?*	**Gaurav Goel** *What Is Algebraic Geometry, and Why Do We Care?*
1:50 - 2:35 PM	**Michael Sipser** *Beyond Computation: What are the Theoretical Limitations of Computer Power?*	**Scott Sheffield** *Entropy*	**Adam Hesterberg** *Wagner's Theorem and Planar Graphs*	**Hahn Lheem** *What Does Math Look Like in College? 9 Topics in 36 Minutes*
2:40 - 3:25 PM	**Scott Kominers** *Two-Sided Matching In Theory and Practice*	**Maya Sankar** *What's In Your CPU?*	**Ted Pyne** *Pseudorandomness In Small Space*	**Jeffery Yu** *Number Theory Beyond the Integers*
PANELS (in **Education Room 1: link.hmmt.org/ed1**)				
4:00 - 4:40 PM	***How to Run a Virtual Tournament*** Talk / Q&A with HMMO November Tournament Directors			
4:45 - 5:25 PM	***Problems Panel*** Talk with HMMO November Problem-Writers			
5:30 - 6:10 PM	***College Life Panel*** Studying Mathematics in College and the College Experience			

Education Events

Joe Blitzstein

The Probabilistic Method: Using Probability to Prove Existence

1:00 - 1:45 PM | Education Room 1

We will introduce the probabilistic method, a beautiful problem-solving strategy (pioneered by Paul Erdos) in which a problem that at first sight has nothing to do with probability can be solved by introducing randomness. In the probabilistic method, we prove the existence of an object with certain desired properties by creating a suitable way to generate random objects. This method has been applied to graph theory, combinatorics, information theory, and other fields.

Joe Blitzstein is Professor of the Practice in Statistics at Harvard, where he has taught since 2006, after completing his Ph.D. in Mathematics (with a Master's in Statistics) at Stanford, advised by Persi Diaconis. He is originally from Los Angeles, California, and did his undergraduate studies in Mathematics at the California Institute of Technology. At Harvard, he has taught a wide range of undergraduate and graduate probability and statistics courses, including the popular statistics class Stat 110, which provides a comprehensive introduction to probability. Stat 110 has grown to over 500 students per year at Harvard, and is also available in MOOC form on edX. Joe's main research interests are in statistical inference for networks, "big data", and other complex data structures. Joe is also a chess expert, and serves as faculty adviser to the Harvard Chess Club.

Technicality/Prerequisites: Basic familiarity with probability and expected values. This will be a lecture with student input.

Yufei Zhao

Equiangular Lines and Spectral Graph Theory

1:00 - 1:45 PM | Education Room 2

Equiangular lines are configurations of lines all passing through the origin and pairwise making the same angle. I will tell you about these fascinating objects and explain how they are related to graph theory.

Last summer, together with an MIT team of students and postdocs, we solved a longstanding problem in discrete geometry by determining the maximum number of equiangular lines with a fixed angle in high dimensions. I will tell you about our result.

Yufei Zhao is an Assistant Professor of Mathematics at MIT. His research area is combinatorics, in particular extremal, probabilistic, additive combinatorics as well as discrete geometry. He has received a Dénes König Prize and a Sloan Research Research Fellowship. At MIT his teaching and mentorship has been recognized with a First Year Advisor Award for his Putnam Seminar, as well as an UROP Outstanding Mentor Award for his supervision of undergraduate research.

Technicality/Prerequisites: Some understanding of linear algebra (in particular, eigenvalues) would be helpful. This is a technical lecture-style talk with some student proofs.

Jon Gruber

Healthcare in the U.S.: What Happens Now?

1:00 - 1:45 PM | Education Room 3

Health care is the one of the largest and most important sectors of the U.S. economy. Professor Jonathan Gruber has helped design some of the key health care reforms of the past two decades. He will explain how these reforms have worked and what happens next in the wake of the U.S. election.

Dr. Jonathan Gruber is the Ford Professor of Economics at the Massachusetts Institute of Technology, where he has taught since 1992. He is also the former Director of the Health Care Program at the National Bureau of Economic Research, and the former President of the American Society of Health Economists. 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.

Technicality/Prerequisites: This is a non-technical talk. No prerequisites are required.

Gaurav Goel

What is Algebraic Geometry, and Why Do We Care?

1:00 - 1:45 PM | Education Room 4 | Stream Link

Algebraic geometry is one of deepest branches of mathematics today and is at the forefront of modern research. It started with René Descartes' 1637 observation that to study geometrical questions, we could translate them into the language of algebra; this had far-reaching consequences and dictated mathematical thought for centuries to come. Algebraic geometers today study properties of objects called "algebraic varieties", which are higher dimensional analogs of plane curves. I will talk about the historical development of algebraic geometry, starting from the conics of the ancient Greeks and talking about classical theorems like those of Bezout, Cayley-Bacharach and Pascal. I will also briefly touch upon modern directions of research in algebraic geometry, including arithmetic geometry and applications to string theory, concluding with a brief discussion of why I find algebraic geometry fascinating.

Gaurav Goel is an undergraduate at Harvard studying mathematics and music. He comes from Mumbai. His current interests include algebraic and differential topology and algebraic geometry. Outside of math, Gaurav loves singing, reading, and playing table tennis. His all time favorite author is J. R. R. Tolkien, and he usually spends hours on end geeking about *The Silmarillion*.

Technicality/Prerequisites: Mathematical maturity is required. An understanding of plane Cartesian geometry is essential, and knowledge of calculus/solid geometry would be helpful. This will be lecture-style, with some student input.

Michael Sipser

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

1:50 - 2:35 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: This will be a non-technical talk.

Scott Sheffield

Entropy

1:50 - 2:35 PM | Education Room 2

Entropy is a quantity in probability theory and thermodynamics which helps measure the amount of "randomness" or "disorder" in a system. In this talk, Professor Sheffield will provide a mathematical introduction to this important topic.

Scott Sheffield is the Leighton Faculty Professor of Mathematics at the Massachusetts Institute of Technology. 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. In 2014 he was awarded a Simons Fellowship in Mathematics. In 2017 he was elected by Society members to the Editorial Board Committee of the American Mathematical Society, February 2017 to January 2020. He currently serves as the Postdoc Officer (effective July 2019) in the Mathematics Department. Since 2011, Sheffield has taught 18.600, the introductory probability course at MIT.

Technicality/Prerequisites: This is a technical lecture-style talk.

Adam Hesterberg

Wagner's Theorem and Planar Graphs

1:50 - 2:35 PM | Education Room 3

In this class, we will discuss the history of this question, including Gödel's letter, and some of the efforts that have been made toward its resolution. You can read a summary of this theorem on its Wikipedia page: https://en.wikipedia.org/wiki/Wagner%27s_theorem.

Adam Hesterberg studied math at Princeton University and got his PhD from MIT under Professor Erik Demaine. He is now Assistant Director of Undergraduate Studies in CS at Harvard. He frequently teaches at Canada/USA Mathcamp, a high school summer program.

Technicality/Prerequisites: This is a technical session.

Hahn Lheem

What Does Math Look Like in College? 9 Topics in 36 Minutes

1:50 - 2:35 PM | Education Room 4 | Stream Link

So you've taken AP Calculus, you know a bit of number theory from math contests, and maybe you've meddled around with some linear algebra in a physics class. But what comes after all this? Well, a lot. This talk aims to touch on 9 topics, ranging from complex analysis to category theory, in 9 times 4 minutes. Along the way, we'll get a glimpse at some remarkably cool concepts and hints as to why all these different subjects exist in the first place.

Hahn Lheem is an intended sophomore currently on leave from Harvard University. Hahn was an avid math competitor in middle and high school whose excitement towards math has only sustained in college, especially once he realized just how much exists in math beyond the four subjects tested in most math contests. In close relation to his interest in math, he greatly enjoys teaching math and hopes to continue spreading mathematical opportunities to everyone. Beyond his endeavors in math, Hahn loves exploring films, discovering great pieces of classical music, watching lots of soccer, and playing various card games.

Technicality/Prerequisites: Knowledge of calculus may be helpful, but is not necessary, for roughly a third of the topics covered. This will be mainly lecture-style.

Scott Kominers

Two-Sided Matching In Theory and Practice

2:40 - 3:25 PM | Education Room 1

Ever wondered what mathematics has to do with both marriage and medicine? Join us for this foray into the theory (and practice) of "stable matching".

Scott Kominers is an Associate Professor of Business Administration in the Entrepreneurial Management Unit at Harvard Business School, and a Faculty Affiliate of the Harvard Department of Economics. He is also an Affiliate of the Harvard Center of Mathematical Sciences and Applications, an Associate of the Harvard Center for Research on Computation and Society, and a Research Economist at the National Bureau of Economic Research. He serves as an Associate Editor of Management Science and Journal of Mechanism and Institution Design, and periodically writes for Bloomberg Opinion.

Technicality/Prerequisites: No prerequisites are required. This will be a non-technical talk.

Maya Sankar

What's In Your CPU?

2:40 - 3:25 PM | Education Room 2

The CPU (Central Processing Unit) is the part of your computer that does all the hard work, whether you're running some code, browsing the internet, or sitting in a Zoom lecture. But how does what you type on a screen translate to physical changes in a circuit? In this class, we will give an overview of how a CPU functions, starting with the chemistry underlying logic gates, and building up to computational units, memory, and more.

Maya Sankar majored in math and computer science at MIT and is currently a first-year PhD student studying math at Stanford. She is interested in combinatorics and computer systems. Outside of school, Maya loves to play music, read, and knit, and is delighted to be back on the West Coast where she can enjoy the sun all year round.

Technicality/Prerequisites: It would be helpful, but it is not required, to have seen Boolean logic before (i.e. statements with AND, OR, NOT). This will be lecture-style, but there may be some student interactivity (completing logic circuits). This talk intends to give a general overview of the subject.

Ted Pyne

Pseudorandomness in Small Space

1:50 - 2:35 PM | Education Room 3

You're dropped in Boston and told to drive to SF. Unfortunately, you're not given a map, and you can only remember 23 intersections at once.

Q: Can you make it?

A: Yup - we'll give a randomized algorithm for this problem.

Q: Can you make it without flipping coins?

A: Yes, if you only drive on interstates. If not, we don't know!

We'll talk about randomness in small space computation, and existing progress (and open problems) in the field.

Ted Pyne is a junior at Harvard majoring in mathematics. He's interested in statistics and theoretical computer science, and in particular understanding the power of randomness in computation. Other than that, he likes running, board games, and kickboxing.

Technicality/Prerequisites: Familiarity with some graph theory. This will be lecture-style but non-technical.

Jeffery Yu

Number Theory Beyond the Integers: Complex Numbers and Other Fields

2:40 - 3:25 PM | Education Room 4 | Stream Link

A Gaussian integer is a complex number a+bi where a and b are integers. While we normally associate number theory with rational integers, we can also do number theory over Gaussian integers! 5 is no longer prime since it factors as (2+i)(2-i), while things like 10+3i are prime. And number theory doesn't stop there - we can consider other number fields such as numbers of the form $a+b\sqrt{2}$. If you get too exotic, then you lose the idea of prime factorization! What happens then? This is the world of algebraic number theory, and we'll use it to find perfect cubes that are 2 more than a perfect square. (27 and 25 is one pair, can you find any others?)

Jeffery Yu is a junior at MIT studying math and physics. He specializes in number theory and quantum information, though his broad mathematical interests span the entire range from pure abstract math to its applications in physics and computer science. As a former avid participant in math contests, he is now focused on the organizing side, as well as exposing students to cool topics outside the typical scope of contests. He was a Tournament Director of HMMT in 2019-20, and remains an active advisor today.

Technicality/Prerequisites: Knowledge of elementary number theory and complex number arithmetic. This session is intended for a variety of backgrounds—you can understand the main ideas just from knowing prime factorization/complex number multiplication. Some advanced topics will be discussed for those with stronger backgrounds.

Panels

Open to all HMMO participants! No prerequisite knowledge required.

All panels will be held in Education Room 1, and will also be streamed at this link.

How to Run a Virtual Tournament

4:00 - 4:40 PM

Chat with the Tournament Directors (TDs) of the November HMMO and get an inside look at HMMT! How does HMMT work behind the scenes? What goes into planning a (virtual) math competition? Hear from present & past tournament directors about what we love (and hate) about planning HMMT in a virtual format and coordinating the logistics of an global, online competition, with audience Q&A.

Problems Panel

4:45 - 5:25 PM

Join the masterminds behind the HMMO November problems as they discuss some problems they wrote—including solution walkthroughs—along with the process of designing original questions and creating the test.

College Life Panel

5:30 - 6:10 PM

Panelists from Harvard and MIT will discuss general life in college and what it's like studying mathematics. Currently scheduled for 40 minutes, but we might stick around for a bit longer!

For more details on the College Life Panel, refer to the event flyers here: link.hmmt.org/edpanel.