MATHEMATICS PROGRAMS THAT PREPARE UNDERGRADUATES FOR CAREERS IN INDUSTRY

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A need for better modeling and simulation methods and technologies

A workforce more capable of interdisciplinary design.

Better tools and understanding for analyzing uncertainty and risk

Greater capabilities for dealing with large data sets.

New methods for coping with complex systems.

Improved capabilities for predicting and understanding market behavior.
ATTRACT AND RETAIN STUDENTS INTO MATHEMATICAL SCIENCES THROUGH:

- **New & Modernized Curriculum**
  - Cuts through the jargon of various disciplines
  - Develops a rigorous foundation in mathematics, statistics
  - Gain strong technical skills in both computation and data analytics

- **Horizontal Integration Across Multiple Quantitative Disciplines**
  - Gives students a broad exposure to several interdisciplinary fields
  - Allows each student to have a primary area of specialization.

- **Leadership & Soft-Skills Training**
  - Foster socialization and team-building amongst groups of students
  - Networking opportunities with scholars and industry leaders

- **Capstone Experience**
  - Either undergraduate research or an internship
  - Offers rich opportunities for growth outside of the classroom.
  - Launch into next stage of education or career.
Freshman & Sophomore Years
- General Education Requirements
- Minor in Mathematics (3 Calculus, Linear Algebra, ODE, proof)
- Intro Computer Programming (C++)
- First Semester of Real Analysis (Abbott/Blue Rudin)

Junior Year
- Mathematical Analysis—Linear and Nonlinear
- Design, Analysis & Optimization of Algorithms
- Concentration classes

Senior Year
- Modeling w/ Uncertainty & Data
- Modeling w/ Dynamics and Control
- Concentration projects
# FIRST YEAR SEQUENCES

## Mathematical Analysis
- Vector Spaces
- Linear Transformations
- Inner Product Spaces
- Spectral Theory
- Metric Topology
- Differentiation
- Contraction Mappings
- Integration
- Integration on Manifolds
- Complex Analysis
- Adv. Spectral Theory
- Pseudospectrum

## Algorithm Design & Optimization
- Intro Algorithms
- Graph Algorithms
- Discrete Probability
- Fourier Theory
- Wavelets
- Interpolation
- Unconstrained Optimization
- Convex Analysis
- Linear Optimization
- Nonlinear Optimization
- Dynamic Optimization
- Markov Decision Processes
FIRST YEAR LABS

Mathematical Analysis

- Intro Python
- Complexity/Sparse Matrices
- Linear Systems
- QR
- Markov Chains
- Facial Recognition (SVD)
- Conditioning
- Newton Cotes vs. Monte Carlo
- Sparse Grid Approximation
- Variance Reduction Methods
- Complex Analysis
- Profiling and Wrapping
- PageRank on Tournaments
- Arnoldi Iteration and GMRES
- The Pseudospectrum
- Relational databases and SQL

Algorithm Design & Optimization

- Data Structures
- Depth/Breadth First
- Nearest Neighbor Search
- Scientific Visualization
- Maximum Likelihood Estimation
- FFT and Applications
- Wavelets
- Chebychev Polynomials
- Polynomial Interpolation
- Optimization Packages
- Line Search Methods
- Conjugate Gradient Methods
- Simplex Method
- Compressed Sensing Lab
- Interior Point Methods
- Dynamic Optimization
- Multi-Armed Bandits
# SECOND YEAR SEQUENCES

## Modeling with Uncertainty & Data
- Random Spaces & Variables
- Distributions & Expectation
- Markov Processes
- Information Theory
- Kalman Filtering & Time-Series
- Principal Components
- Clustering
- Bayesian Statistics (MCMC)
- Logistic Regression
- Random Forests
- Support Vector Machines
- Deep Neural Nets

## Modeling with Dynamics & Control
- ODE Existence & Uniqueness
- Linear ODE
- Nonlinear Stability
- Boundary-Value Problems
- Hyperbolic PDE
- Parabolic PDE
- Elliptic PDE
- Calculus of Variations
- Optimal Control
- Stochastic Control
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LEADERSHIP AND SOFT-SKILLS TRAINING

• Resumes
• Cover Letters
• Interviews
• Internships
• How to give a talk
• Listening

• Conflict Management
• Negotiation
• Leadership
• Running a Meeting
• Project Management
• Working in Teams
• Networking
RECENT INDUSTRY VISITS

- Amazon
- Nike
- Raytheon
- Goldman Sachs
- NSA
- Sandia
- Google
- Capital One
- Towers Watson
- Intermountain Healthcare
- UnitedHealth
- MITRE
- Ford
- Recursion
Final Talking Points

- **Revised and Fixed Curriculum is Powerful**
  - Reuse not review
  - Integration across topics
  - Multi-disciplinary perspective

- **Cohort Model is Effective**
  - Retention
  - Socialization, Team-Building
  - Strong Alumni Base
  - They become BFFs
PREPARATION FOR INDUSTRIAL CAREERS IN MATHEMATICAL SCIENCES (MAA PIC MATH)

Michael Dorff
Suzy Weeks
Sample problem

**Background:** Youngstown, Ohio has seen a dramatic decline in its city population and a shift in the location of the population over the past forty years. However, the police department was still using a division of the city into police beats that was created decades ago. You are given crime data from the past year from the police department.

**Problem:** Propose a new model for more equitable divisions of the city into police beats.
Imagine a course based on solving problems from BIG

**A course that**
- is based on an actual problem from industry
- the problem can be solved by 1st and 2nd year undergraduates
- students work in groups solving a problem from industry
- the instructor does little (or no) lecturing
- students interact with a consultant from industry
- involves students improving their communication skills
- prepares students for careers
That course is MAA PIC Math!

PIC Math prepares math and stats students for industrial careers by engaging them in research problems from industry.

This is a national program that is funded by NSF.

**Components:**
- summer 3-day faculty training workshop
- spring semester course for students (research paper and presentation)
- student conference
Participation data (2014-2016)

- 107 faculty members
- 101 U.S. universities/colleges
  - In 32 states and D.C.
  - 14 PhD, 23 MS/MA, 63 BS/BA, 1 Associates
  - 10 HSIs and 6 HBCUs
- Over 1400 undergraduate students
  - 40% female
  - 21% underrepresented ethnic groups
- 147 paper co-authored by ugrads
- Over 150 conference presentations by ugrads
- Over 100 industrial partners who have provided problems and consultants
Female student at SUNY Geneseo: “I gained so many valuable skills in problem solving and working with a team. This opportunity was truly a stepping-stone for my career in mathematics.”

Female student at Virginia State Univ (HBCU): “The PIC math helped me get my first job. The experience of successfully working in groups, and problem solving were key components in my interview.”
Faculty Comments:

Elly Farnell, Kenyon College: Students in my courses have now gained valuable experience in team-based research on open-ended problems that have an immediate impact in a real-world setting.

Tom Wakefield, Youngstown State Univ: “The students were so committed to the project and excited to work on a problem with practical implications."
Spring semester course

Logistics:

- 5-15 ugrads in class
- students learn by doing (not by a lecture)
- students work in groups
- students solve problems from industry
- course material provided
- students write a paper and give a talk
Resources for teaching the course

- Syllabus and course schedule
- Written research problems from industry
- Videos of industry mathematicians explaining a problem
- Videos of professors explaining the solution to the problem
- Student papers solving the research problem
- Videos of students presenting their research
Sample problem 2

Background: Kongregate is an online browser-based video game website. They are combating ratings fraud by players using fake accounts to influence the ratings of games substantially.

Problem: Using data provided by Kongregate, develop an algorithm to help determine whether a submitted account is real or fraudulent.
Sample problem 3

**Background:** The Field Museum is the science museum in Chicago. They implemented a crowdsourcing project designed to classify a large sample of microscopic plants, and obtained hundreds of thousands of pieces of data. While most of the crowdsourced data were usable, some were not.

**Problem:** Come up with criteria for determining what data are usable and what data should be rejected.
Over 100 industry partners have provided problems and a consultant who helps the students. These partners include:

- Field Museum of Chicago
- Coca Cola
- Habitat for Humanity
- Colorado Dept of Transportation
- Heart Artery and Vein Center of Fresno
- Los Alamos National Lab
- City of Kansas City
- Massachusetts General Hospital
- AIG Insurance
- National Security Technologies
- Greensboro NC Police Dept
- Applied Geographics
- Water Utility Group
- Sandia National Lab
3-day faculty summer workshop:

Discussion topics:
- non-academic careers and internships
- types of research problems that arise in industry
- how to develop skills in students valued in industry
- guidance on developing industry connections
- preparation for spring course
Program details are available at www.maa.org/picmath

contact Michael Dorff
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Faculty Training Workshop on Data Science

For non-data science math and stat faculty who
- want to learn more about data science
- want to learn the basics on how to solve data science problems

- 2017, 2019 at BYU
- 2020 SAMSI (June 15-18)
- 2020 ICERM (July 20-24)
Thank you!

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Get out of your comfort zone!