Mathematical Sciences at WPI

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Mathematical Sciences
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What do Mathematicians Do?

“The universe cannot be read until we have learned the language and become familiar with the characters in which it is written. It is written in mathematical language, and the letters are triangles, circles and other geometrical figures, without which means it is humanly impossible to comprehend a single word. Without these, one is wandering about in a dark labyrinth”

Galileo Galilei (1564-1642)

Through their work, Mathematicians build a language that allows us to experience in a quantitative and self consistent fashion the complexity of nature. The language is used by Physicists, Engineers, Economists,...
A powerful language: Calculus

Gottfried Wilhelm Leibniz (1646-1716)

Isaac Newton (1643-1727)
Math allows us to experience infinity

**Normal numbers** are special numbers in which every sequence of digits will sooner or later appear in their decimal representation.

For instance the number

\[0.12345678910111213\ldots\]

has this property.

What do they have to do with understanding infinity?
Math allows us to experience infinity

This number contains any discrete data imaginable.

For instance... your SSN, all your credit card numbers...
Math allows us to experience infinity

This screenshot, is represented in the pdf file as a list of 0 and 1 and so it is encoded as a number which is contained in any normal number.

Any image that can be represented in this way is contained in any normal number...
Math allows us to experience infinity

This number contains any possible picture of you as a baby

... as well as all other babies in history
Math allows us to experience infinity

This number contains any possible sound, encoded as mp3 file. This means any performance of any song ...

... any piece of music that has ever been written

... Any tune you have ever whistled in the shower ...
Math allows us to experience infinity

Mathematicians can prove that ALMOST EVERY NUMBER (in a precise mathematical sense) has this property, but currently we do not have any algorithm to decide whether a given number, for instance $\pi$, is normal or not.
Why study Mathematics?

In 1960 Physics Nobel prize Eugene Wigner wrote a famous article in which he observed how Mathematical Structures used to model Physical Theories often (and inexplicably) lead to further advances in that theory.

"... and it is probable that there is some secret here which remains to be discovered." (E. S. Peirce)

There is a story about two friends, who were classmates in high school, talking about their jobs. One of them became a statistician and was working on population trends. He showed a print to his former classmate. The reprint started, as usual, with the Gaussian distribution and the statistician explained to his former classmate the meaning of the symbols for the actual population, for the average population, and so on. His classmate was a bit incredulous and was not quite sure whether the statistician was pulling his leg. "How can you know that?" was his query. "And what is this symbol here?" "Oh," said the statistician, "this is $\pi$. What is that?" "The ratio of the circumference of the circle to its diameter."

"Well, now you are pushing your joke too far," said the classmate, "surely the population has nothing to do with the circumference of the circle."

Naturally, we are inclined to think about the simplicity of the classmate’s approach. Nevertheless, when I heard this story, I had to admit to an eerie feeling because, surely, the reaction of the classmate betrayed only plain common sense. I was even more confused when, not many days later, someone came to me and expressed his bewilderment with the fact that we make a rather narrow selection when choosing the data on which we test our theories. "How do we know that, if we made a theory which focuses its attention on phenomena we disregard, some of the phenomena now commanding our attention, that we could not build another theory which has little in common with the present one but which, nevertheless, explains just as many phenomena as the present theory?" It has to be admitted that we have at least definite evidence that there is so much theory.

The preceding two stories illustrate the two main paths which are the
Medical imaging and math

• At the heart of every medical imaging technology is a sophisticated mathematical model of the measurement process and an algorithm to reconstruct an image from the data.

• Key Mathematical instrument is the inverse of the Radon Transform
Johann Radon (1887-1956)

Radon Transform introduced In 1917. A long time before The technology for medical Imaging was developed.

This is an example of how “pure” math becomes “applied” math over centuries.
Why study Mathematics?

• Because you are drawn to logical analysis, patterns and structure (you have the “math gene”).

• Because it is a powerful and beautiful language that can be used to model and predict systems from biology, physics, engineering, ...

• Because it opens up a wide range of appealing job opportunities...
# Why study Mathematics?

## Competitive Salaries

<table>
<thead>
<tr>
<th>Rank</th>
<th>Major</th>
<th>Degree Type</th>
<th>Early Career Pay</th>
<th>Mid-Career Pay</th>
<th>% High Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Petroleum Engineering</td>
<td>Bachelor's</td>
<td>$94,600</td>
<td>$175,500</td>
<td>65%</td>
</tr>
<tr>
<td>2</td>
<td>Actuarial Mathematics</td>
<td>Bachelor's</td>
<td>$56,400</td>
<td>$131,700</td>
<td>49%</td>
</tr>
<tr>
<td>3</td>
<td>Actuarial Science</td>
<td>Bachelor's</td>
<td>$61,200</td>
<td>$130,800</td>
<td>43%</td>
</tr>
<tr>
<td>4</td>
<td>Nuclear Engineering</td>
<td>Bachelor's</td>
<td>$69,000</td>
<td>$127,500</td>
<td>72%</td>
</tr>
<tr>
<td>5</td>
<td>Chemical Engineering</td>
<td>Bachelor's</td>
<td>$70,300</td>
<td>$124,500</td>
<td>57%</td>
</tr>
<tr>
<td>6</td>
<td>Marine Engineering</td>
<td>Bachelor's</td>
<td>$73,900</td>
<td>$123,200</td>
<td>68%</td>
</tr>
<tr>
<td>7</td>
<td>Economics and Mathematics</td>
<td>Bachelor's</td>
<td>$60,000</td>
<td>$122,900</td>
<td>36%</td>
</tr>
<tr>
<td>8</td>
<td>Geophysics</td>
<td>Bachelor's</td>
<td>$54,100</td>
<td>$122,200</td>
<td>N/A</td>
</tr>
<tr>
<td>9</td>
<td>Cognitive Science</td>
<td>Bachelor's</td>
<td>$54,000</td>
<td>$121,900</td>
<td>40%</td>
</tr>
<tr>
<td>10</td>
<td>Electrical Power Engineering</td>
<td>Bachelor's</td>
<td>$68,600</td>
<td>$119,100</td>
<td>70%</td>
</tr>
<tr>
<td>11 (tie)</td>
<td>Aeronautical Engineering</td>
<td>Bachelor's</td>
<td>$65,300</td>
<td>$118,800</td>
<td>61%</td>
</tr>
<tr>
<td>11 (tie)</td>
<td>Electrical &amp; Computer Engineering (ECE)</td>
<td>Bachelor's</td>
<td>$69,000</td>
<td>$118,800</td>
<td>51%</td>
</tr>
<tr>
<td>13</td>
<td>Computer Systems Engineering</td>
<td>Bachelor's</td>
<td>$72,000</td>
<td>$118,000</td>
<td>N/A</td>
</tr>
<tr>
<td>14 (tie)</td>
<td>Bioengineering (BioE)</td>
<td>Bachelor's</td>
<td>$61,600</td>
<td>$116,800</td>
<td>68%</td>
</tr>
<tr>
<td>14 (tie)</td>
<td>Computer Science (CS) &amp; Engineering</td>
<td>Bachelor's</td>
<td>$70,900</td>
<td>$116,800</td>
<td>42%</td>
</tr>
</tbody>
</table>

Top Ten Majors by Salary potential.

[www.payscale.com](http://www.payscale.com) 2018

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Worcester Polytechnic Institute
Salaries of 2017 WPI grads

• WPI wide employment rate is 91.7%
• WPI wide BS grads salary: $66,983
• **Math Sciences grads: $67,500 - Higher than the average.**
• Math is ranked #9 among over 90 WPI majors and programs in terms of initial salary.
2014 Ranking of the Best and Worst Jobs

1. MATHEMATICIAN
   Applies mathematical theories and formulas to teach or solve problems in a business, educational, or industrial climate.

2. STATISTICIAN
   Tabulates, analyzes, and interprets the numeric results of experiments and surveys.

3. ACTUARY
   Interprets statistics to determine probabilities of accidents, sickness, death, & property loss from theft & natural disasters.
Where do Mathematicians Work?

- Arts, entertainment, and recreation
- Education
- Finance and insurance
- Government
- Health care and social assistance
- Information technology
- Legal services
- Management of companies & enterprises
- Manufacturing
- Nonprofit
- Other science and technology
- Retail trade
- Transportation & warehousing
- Utilities

http://www.ams.org/early-careers/
Mathematics and Big Data

Analysis of large sets of data, be they genetic markers (220 millions base pairs) or Netflix preferences (matrix composed of 50 millions rows and about 20,000 columns), is carried out through an intense use of mathematics and statistics.

WPI’s DATA SCIENCE program blends Math, CS and business.
100 powerful supercomputers perform geometrical, algebraic and calculus-based calculations to animate Pixar's characters.
Mathematics in Entertainment

Aleka McAdams, a mathematician working at Disney Studios used math modeling and computational physics to do realistic hair simulations in the movies Tangled and Frozen.
Mathematics in Entertainment

The laws of physics that describe the dynamics of fabric movement are modeled by mathematicians and used in computer graphics and in animations.

Pafnuty Chebyshev
What is Math Used For?

- Automobile and aircraft design
- Oil recovery
- Understanding cardiovascular diseases
- Understanding the spread of diseases
- Bringing architectural design to reality
- Understanding movement of bird flocks
- Predicting climate and weather
- Figuring out the best way to board an airplane
- Manufacturing better eyeglass lenses
- Finding the effects of voting procedures on election results
- Computer graphics and animation
- Internet encryption
- Data storage on CDs and DVDs
- Designing efficient water purification systems

http://www.ams.org/mathmoments
Mathematical Sciences @WPI

- Mathematical Sciences Major
  - Mathematics; Statistics (MA degree)
  - Actuarial Mathematics (MAC degree)
- Mathematics minor
- Statistics minor

- It is also a required foundation for studying engineering, physics, technology, management, finance,...
Mathematical Sciences Department

105+ Undergraduates
110+ Graduate students (MS and PhD)
29+ Tenured & Tenure-Track Faculty
8 Postdoctoral Scholars
8 Teaching Professors

In recent years:

10 NSF research awards, 2 NIH awards, 1 Air Force award, 1 NSF REU, 1 NSF MPI, and several others.
3 NSF CAREER Fellows
2015 Trustees’ Award for Outstanding Service to the Community
2010, 2015 Trustees’ Award for Outstanding Research & Scholarship
2007, 2008, 2010 Trustees’ Award for Outstanding Teaching
2008 Kalenian Award for Entrepreneurship & Innovation
2007, 2016 Trustees’ Award for Outstanding Academic Advising
Mathematical Sciences Program

Mathematical Sciences
- Algebra/Discrete Mathematics
- Math Modeling/Applied Math
- Mathematical Biology.
- Analysis, Calculus of Variations, Computational Mathematics.
- Financial Mathematics
- Statistics-Probability

Actuarial Mathematics

Joint Programs
- Bioinformatics
- Data Science

BS/MS Programs
- Applied Math
- Applied Statistics
- Financial Math
- Industrial Math

Minors in Math or Statistics

Worcester Polytechnic Institute
Faculty Research

Actuarial Mathematics

Algebra/Discrete Mathematics
- Abstract Algebra
- Coding Theory and Cryptography
- Graph Theory and Combinatorics

Analysis/Differential Equations
- Calculus of Variations
- Free and Moving Boundary Problems
- Mathematical Physics
- Partial Differential Equations
- Stochastic Analysis
Faculty Research

Financial Mathematics
• Systemic Risk

Mathematics of Materials Science
• Composite Materials/Homogenization
• Fracture and Damage
• Mathematical Geophysics
• Porous Electrodes (fuel cells, batteries)

Numerical Analysis/Computational Modeling
• Computational Modeling
• Large Scale and Parallel Computing
• Numerical Analysis
Faculty Research

Mathematical Biology
- Cardiovascular Modeling and Biomechanics
- Cell Motility
- Population Dynamics

Statistics
- Bayesian Statistics
- Biostatistics and Bioinformatics
- Statistical Decision Theory & High-dimensional Data Analysis
- Statistical Genetics
- Survey Methodology
- Time Series
Where our graduates go...

• Industry
  – Raytheon, Pratt & Whitney, General Mills ...
  – Microsoft, Alphatech, MathWorks, ...
  – Harrah’s Entertainment, ...

• Actuarial and financial careers
  – Aetna, Allmerica, Sun Life, Hanover, Unum, ...
  – Fidelity Investments, Putnam, HIMCO, ...

• Consulting firms
  – Accenture, Towers-Perrin, SAIC, ...

• Graduate schools
WPI Undergraduate Experience

- Flexibility with four terms per year
- Close interaction with faculty
- Collaborating with faculty active in fundamental research (MQP)
- Good job and graduate school prospects
WPI First Year Focus

- Mathematics
- Science
- Humanities or Social Science
First Year Mathematics

- Traditional Calc Sequence: MA1021-1024
- Calculus with Review: MA1020, 1120
- Analysis Sequence: MA1033-1034
- Bridge to Higher Math: MA1971
- Linear Algebra, Differential Equations, Probability, Statistics...
“Traditional” Calculus MA1021-1024

- **MA1021** – Derivatives and applications
- **MA1022** - Integrals and applications
- **MA1023** – Infinite Series, Parametric Curves, Vectors
- **MA1024** – Partial Derivatives and Multiple Integrals

All are term-length courses for 1/3 unit credit
Calculus with Pre-Calculus Review

- **MA1020** – Derivatives and applications
  - Semester-long (14 weeks) course in the fall
  - Pre-Calculus Review!

- **MA1120** – Integrals and applications
  - Semester-long course in the spring
The Analysis Sequence

MA1033 in A term, MA1034 in B term,

• Rigorous treatment of calculus III and IV (with proofs)

• Appropriate for math majors and those who want the theory behind the calculus
MA1971: Bridge to Higher Mathematics

- Introduction to mathematical thinking
- Develop mathematical logic and reasoning skills
- Learn to explain, justify, defend, disprove, conjecture and verify mathematical ideas, both verbally and in writing
- Recommended for all Mathematical Sciences majors (MA & MAC)
Advanced Placement Credit

• College Transfer Credit

• Advanced Placement (AP) Exam

• WPI Retroactive Credit
AP Exam Credit

- **4 or 5 on AB exam**
  - Credit for Calculus I and Calculus II
  - Take Calculus III in A term
  - Take Calculus IV in B term

- **4 or 5 on AB exam**
  - Credit for Calculus I, II, and III
  - Take special Calculus IV in A term
  - Take special Differential Equations in B term
  - Take special Linear Algebra MA2072 in C term
Retroactive Credit

• Get free credit for Calculus I if*
  – Take and pass Calculus II in first year
  – Take and pass Calculus III in first year

• Get free credit for Calculus I and II if*
  – Take and pass Calculus III in first year
  – Take and pass Calculus IV in first year

* No changes and no substitutes, no math NRs
For Math Majors after the First Year

- Choose a Concentration... Transition Courses
  - Math Modeling with Differential Equations
  - Graph Theory, Combinatorics
  - Probability Theory
  - Linear Algebra II

- Upper Level Courses for breadth and depth

- Major Qualifying Project as a capstone
Some Mathematical Sciences MQPs

- Mathematical Model of Brain Tumors
- Differential power analysis side-channel attacks in cryptography
- Robustifying Logistic Regression for Nonresponse: An Application to BMI
- One-dimensional Viscoelastic Cell Motility Model
- Optimal Portfolio Analysis with Turnover Constraints
- Optimization of the Sierpinski Carpet Fractal Antenna
- An Investigation of Polya's Function
- Regulatory Network Models for Biology
- Thin-film Ferrofluidics
- Nanoionic Particle Composite Homogenization
- Network Anomaly Detection Using Robust Principal Component Analysis
- Calibration of an Optimal Bidding Model for the Mobile Advertisement Markets
BS/MS Programs

We have two BS/MS programs, which enable students to obtain both a BS and MS degree with 5 years of study:

• The 5-year BS/MS Program

• The “standard” BS/MS Program
The 5-year BS/MS Program

• Exclusive to Math Sciences Dept
• Apply when applying for admission as a freshman
• If accepted, progress reviewed in junior year
• Work as a PLA while an undergraduate
• 5th year is tuition-free; work as half-time TA
“Standard” BS/MS Program

• Apply in junior year
• If accepted, can double-count courses to enable BS and MS in 5 years
• Available for the following Math Sciences MS programs:
  — Applied Mathematics
  — Applied Statistics
  — Financial Mathematics
  — Industrial Mathematics
Mathematical Sciences Minors

• Can minor in Mathematics or Statistics

• Take 5 Courses + 1 Capstone
Center for Industrial Mathematics and Statistics

- Build connections between academics and business and industry
- Students work on real-world projects that come directly from industry, government and finance

http://www.wpi.edu/+CIMS
CIMS Industrial Partners

200+ students have worked on
110+ industrial projects from
50+ companies
For More Information

http://www.wpi.edu/+MATH