Sloan Career Cornerstone Center

Mathematics Overview

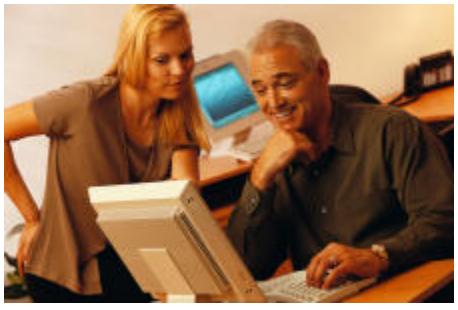
The Field - Preparation - Day in the Life - Applications - Earnings - Employment - Career Path Forecast - Professional Organizations

The Field

Mathematics is one of the oldest and most fundamental sciences. Mathematicians use mathematical theory, computational techniques, algorithms, and the latest computer technology to solve economic, scientific, engineering, physics, and business problems.

The work of mathematicians falls into two broad classes -- theoretical (pure) mathematics and applied mathematics. These classes, however, are not sharply defined and often overlap. The world is full of places to do rigorous mathematics. As you begin to identify potential outlets for your talent, it may be useful to get a sense of the dimensions of the 'field' in its entirety. Business, industry, and government use mathematical expertise, often in the context of applications. However, the job titles often do not include the word "mathematics" or "mathematician," but do involve significant use of mathematics and/or quantitative reasoning.

For people with advanced degrees in mathematics, careers involve development of new mathematical methods and theories and application to almost every area of science, engineering, industry and business. Those who major in mathematics in undergraduate institutions find a broad variety of opportunities. Some use their mathematical training directly and some use their training in rigorous thinking and analysis indirectly to solve problems in the business sector.



Many of the contributions and uses of mathematics are closely related to the need for mathematical modeling and simulation of physical phenomena on the computer. In addition, the analysis and control of processes, and optimization and scheduling of resources use significant mathematics. For example, the finance industry uses sophisticated mathematical models for pricing of securities, while the petroleum industry models the flow of oil in underground rock formations to help in oil recovery. Image processing, whether producing clear pictures from satellite imagery or making medical images (CAT, MRI) to detect and diagnose,

all use significant mathematics. Industrial design, whether structural components for airplanes or automobile parts, uses a tremendous amount of mathematical modeling; much of which is embodied in CAD/CAM computer software. Such techniques were used in the design of the Boeing 777, as well as in the design of automobiles. Computational modeling is also used in airplane and automobile design to analyze the flow of air over vehicles to determine fuel economy and efficiency.

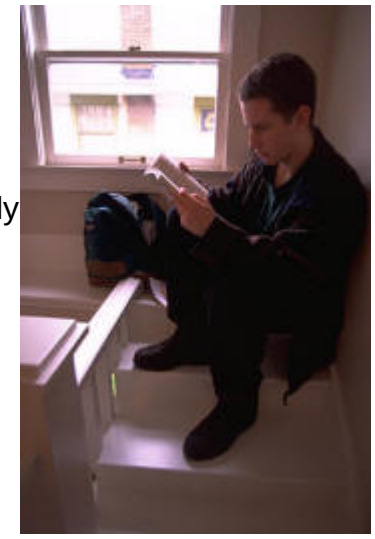
The use of mathematics is pervasive in modern industry. The result is that mathematicians are found in almost every sector of the job market, including engineering research, telecommunications, computer services and software, energy systems, computer manufacturers, aerospace and automotive, chemicals and pharmaceuticals, and government laboratories, among others.

Preparation

A Ph.D. degree in mathematics usually is the minimum educational requirement for prospective mathematicians, except in the Federal Government. In the Federal Government, entry-level job candidates usually must have a 4-year degree with a major in mathematics or a 4-year degree with the equivalent of a mathematics major -- 24 semester hours of mathematics courses.

▶ Ph.D. Training

In private industry, candidates for mathematician jobs typically need a Ph.D., although there may be opportunities for those with a master's degree. Most of the positions designated for mathematicians are in research and development laboratories, as part of technical teams. In such settings, mathematicians engage either in basic research on pure mathematical principles or in applied research on developing or improving specific products or processes. The majority of those with a bachelor's or master's degree in mathematics who work in private industry do so not as mathematicians but in related fields such as computer science, where they have titles such as computer programmer, systems analyst, or systems engineer.



▶ Bachelor's Degree Courses

A bachelor's degree in mathematics is offered by most colleges and universities. A list of current mathematics programs in the U.S. is available at www.careercornerstone.org. Mathematics courses usually required for this degree include calculus, differential equations, and linear and abstract algebra. Additional courses might include probability theory and statistics, mathematical analysis, numerical analysis, topology, discrete mathematics, and mathematical logic. Many colleges and universities urge or require students majoring in mathematics to take courses in a field that is closely related to mathematics, such as computer science, engineering, life science, physical science, or economics. A double major in mathematics and

another related discipline is particularly desirable to many employers. High school students who are prospective college mathematics majors should take as many mathematics courses as possible while in high school.

University Selection

In 2007, there were more than 300 graduate programs, offering both master's and doctoral degrees, in pure or applied mathematics around the country. In graduate school, students conduct research and take advanced courses, usually specializing in a subfield of mathematics.

Specialized Training

For jobs in applied mathematics, training in the field in which the mathematics will be used is very important. Mathematics is used extensively in physics, actuarial science, statistics, engineering, and operations research. Computer science, business and industrial management, economics, finance, chemistry, geology, life sciences, and behavioral sciences are likewise dependent on applied mathematics. Mathematicians also should have substantial knowledge of computer programming, because most complex mathematical computation and much mathematical modeling are done on a computer.

Core Skills

Mathematicians need good reasoning ability and persistence to identify, analyze, and apply basic principles to technical problems. Communication skills also are important, as mathematicians must be able to interact and discuss proposed solutions with people who may not have extensive knowledge of mathematics.

Coops and Internships

Internships, co-ops, and research can be valuable because they allow you to see what it is like to work in your field. Many mathematicians mention hands-on experience before graduating as an asset when looking for a job and as valuable in helping them decide what kind of first job to look for after graduation.

Day in the Life

Real life as a mathematician bears little resemblance to cliché. Not everyone has a Ph.D. in operations research, nor do they spend days at the computer terminal isolated from human contact. In reality, a mathematician's working experience is a matrix of the type of problems you work on and the relationships among the members of your team. You will find that you need to bring a wide range of skills to bear on your various daily activities.

Typical Problems

At the heart of your work will be the kind of mathematics that you do. There are no typical problems any more than there are typical days, but it is possible to get a general idea of the work that goes on. Most problems in the real world require multiple levels of analysis, planning, detail work, and coordination.

Business:

- Problem -- A firm wanted to decide statistically with a given confidence level what is the most it can lose over a given time interval. There are several methods to compute this value, the most precise of which tends to be very time-consuming -- requiring on the order of hours or maybe days to run on a computer, which makes it not feasible for a bank. The challenge is to come up with a quick analytical way to estimate this so-called value at risk.
- Process -- In order to do this, we drew upon techniques from stochastic processes, differential equations, and also Fourier analysis because we implement a Fast Fourier Transform and we used complex arithmetic in its implementation.
- Results -- The analysis resulted in a complete distribution of the firm's future portfolio values. For instance, in one day or five days the full worth of the portfolio could vary by +$50 million to -$7 million or less. We assigned a probability to each of these states. Coming up with such probabilities rigorously involved some fairly interesting mathematics at that level, and it involved other people from the group and collaboration with people overseas. Part of the result of this work was a paper, and it is something that ultimately will get incorporated into our company's product, which is software. In addition, it allowed us to do some interesting research.

Industry:

- Problem -- The goal is to develop a methodology to reduce sonic boom in aircraft design.
- Process -- We use computational fluid dynamics and a computational code to study the flow over the geometry of an aircraft. Once the solution is obtained, we use visualization tools to look at the physical flow field over the aircraft. We use a color monitor, called the work station, to bring the solution up visually. For example, if you want to look at the surface pressure of an aircraft we identify a blue color with the lower pressure, and a red color for the higher pressure. So by looking at the gradients of the color changes we understand the pressure on the surface of the aircraft. From this we understand a little bit more about the physics.
- Results -- Once we have experience with this problem, we start the design phase using computational fluid dynamics codes and changing the shape of the aircraft. Bit by bit we get to what we want to achieve, a reduction in the sonic boom.

Government:

- Problem -- Produce a forecast for Department of Defense budgets of how much production of a particular ship will cost in one year (or five years, ten years or 20 years.) We look at what types of factors will drive overhead costs and what kind of relationships exist when estimating future overhead costs versus how they have behaved in the past.
- Process -- We use a lot of statistical procedures to build models to project these costs into the future. We look at regression analysis and data collection as well as historical data to figure out whether it will be an accurate indicator for what will happen in the future. We actually build models that will give us some sort of overhead estimate to include in our ship cost.
- Results -- Changes occur that make the models nonlinear. Things that happened five years ago are not actually what are happening five years from now and things are just so dynamically changing, that it's very hard to predict what will happen.

Work Environment

Regardless of your job's specifications, it is very likely that you will be part of a team working with people of diverse backgrounds. These colleagues will be a resource for you, as you will be for them. You may be handed assignments directly and given a specific time frame in which to complete them, or your work may derive from a project for which you are generally responsible.

Skills

To accomplish your work successfully you will need more than just your mathematical abilities. The capacity to write well and to articulate your ideas to others is imperative no matter what kind of job you have. In addition to communication and interpersonal skills, familiarity with other technical specialties is important. Often the problems you tackle may originate in other disciplines, and knowing the `vocabulary' for that area may speed your work.

Activities

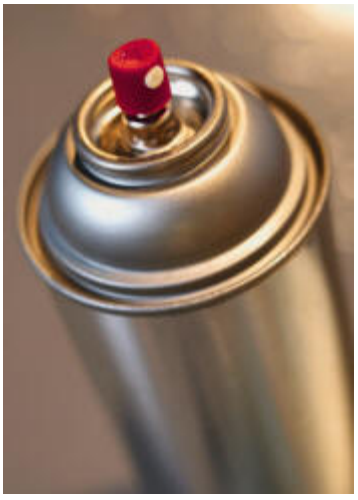
Checking email, planning meetings, calling clients, preparing for conferences, creating budgets, researching problems, hiring staff, developing specifications, assigning tasks, training colleagues, running computer applications, writing reports -- the list of activities you perform in any given day will be diverse and long.

Advice

Once you are on the job, you may find yourself working on projects that require knowledge in areas new to you. Most employers expect this to happen and give you time to obtain the background you need. When looking for a job, you will want to find out what opportunities and training an employer offers so you can stay abreast of changes in your field.

Applications

The spectrum of the field is perhaps best illustrated by observing the role of mathematics as it applies to different products.



Aerosol Can

Chlorofluorocarbons (CFCs), like the freon used in aerosol cans and air conditioning systems, could destroy stratospheric ozone, which protects the earth from biologically damaging ultraviolet radiation. Mathematical models, simulations and the numerical solution of a special set of differential equations, called "stiff" differential equations, are used to identify safer replacements from the members of hydrohalocarbon (HHC) family.

Oil Rig
Accurate models of oil reservoirs, including the simulations of oil and water moving through porous rock, sometimes covering hundreds of acres, are used by the petroleum industry to make decisions on where to drill. These problems are solved by reducing complex multidimensional differential equations to a sequence of simpler one-dimensional problems that are solved numerically

Airport


Operations research is used throughout the airline industry to make sure seats are sold and the airlines make money. Yield management, including mathematical models, optimization techniques, and probability calculations, is used for setting up automated reservation systems and complex systems of connecting routes.

Communications Satellite
Models based on computing solutions to partial differential equations are used to solve problems in signal processing and filtering of noise.

Circuit
The design of a circuit uses the concept of a graph, like a schematic map, with lines, called edges and intersections, called nodes. Systematic searches of the nodes are used to determine the most efficient connection from one node to another.

Aircraft
The design of an aircraft requires computational fluid dynamics, partial differential equations, and grid generation on complex geometries.

CD
CD players, digital audio tape and digital television read digital information that consists of "bits" -- 0's and 1's. Occasionally these devices confuse the two and error-correction codes, like Reed-Soloman codes, are needed. Mathematically, Reed-Solomon codes are based on the arithmetic of finite fields.

Fingerprint
The law enforcement community is interested in developing quick ways to match fingerprints with the database of fingerprints held by the Federal Bureau of Investigation. The problem is the FBI holds approximately 200 million fingerprint cards. They have now adopted a standard for digital fingerprint image compression that will allow the fingerprints to be stored electronically.

Space Vehicle

The equations of motion of a space vehicle are systems of ordinary differential equations. One may wish to solve an initial value problem, say where the initial position and velocity of the spacecraft is given and you want to determine the trajectory for some period of time. Boundary value problems also arise, for example when you want to design an orbit transfer maneuver between two different orbits. In that case you have beginning and end point constraints on the maneuver.

Submarine

The search for enemy submarines requires the application of a number of fields of mathematics, including probability, game theory and optimization.

Space Shuttle

The problem of separation of the space shuttle fuel tank involves ordinary differential equations and numerical solution methods.

Fabric

Color is the result of the combination of a light source, an object that it illuminates, and a visual system to perceive the color which is usually the eye and the brain of a human being working together. Color is commonly described by the attributes of lightness, chroma, and hue. Standardized color descriptions use values assigned to these three attributes to identify the color.

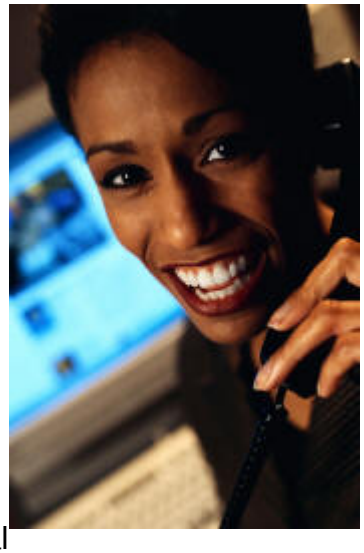
Crystal

Crystal growth can be modeled using partial differential equations.

Earnings

Because of the diversity of the type of work mathematicians do and their employers, the range of compensation is extremely broad. According to the U.S. Department of Labor, Bureau of Labor Statistics, median annual earnings of mathematicians were $86,930 in May 2006. The middle 50 percent earned between $62,970 and $106,250. The lowest 10 percent had earnings of less than $43,500, while the highest 10 percent earned more than $132,190.
In 2007, the average annual salary for mathematicians employed by the Federal Government in supervisory, nonsupervisory, and managerial positions was $93,539; for mathematical statisticians, $96,121; and for cryptanalysts, the average was $90,435.

Employment



Mathematicians hold about 3,000 jobs in the United States. Many people with mathematical backgrounds also worked in other occupations. For example, there were about 54,000 jobs as postsecondary mathematical science teachers.

Many mathematicians work for Federal or State governments. The U.S. Department of Defense is the primary Federal employer, accounting for about 37 percent of the mathematicians employed by the Federal Government. Many of the other mathematicians employed by the Federal Government work for the National Aeronautics and Space Administration (NASA).
In the private sector, major employers include scientific research and development services and management, scientific, and technical consulting services. Some mathematicians also work for software publishers, insurance companies, and in aerospace or pharmaceutical manufacturing.

Mathematicians work in every major sector of the economy: industry, business, government, and academia. These arenas are marked by very definite characteristics that will be important to consider as you explore options.

Industry

Consisting of manufacturing and consumer products companies, this sector is typically characterized by an emphasis on the bottom line. At companies like Boeing, Kodak, and Microsoft, mathematicians report that an appreciation for deadlines, a multiplicity of problems to solve, and the tangible impact of their work on a final product makes this sector personally rewarding.

Business

Companies whose primary function is service-oriented, like consulting or financial analysis, fall into this sector. Business depends on profits and thus offers a mathematician a variety of problems at a challenging pace; however, its profitability is proportional to client satisfaction and therefore might require additional capabilities from its employees -- strong interpersonal and communication skills foremost among them.

Government

The federal government includes organizations as diverse as the national labs, the Federal Reserve, and the U.S. Navy, each with disparate cultures. Despite variance in specific agencies, government work in general is distinguished by the necessity of operating within certain guidelines and procedures. The pace is often quick and the problems challenging. Salary, benefits, and promotions are likely to be dispensed in accordance with regulations.

Titles

A title is like the suit (or jeans, as the case may be) you wear to work. Underneath it all, you're still you. In the nonacademic world, mathematicians wear many different titles. They may be called Analysis Lead, Consultant, Design Engineer, Member of Technical Staff, or Section Head, but they function as mathematicians. Sample titles include:

Actuarial Scientist	Media Specialist
Actuary Assistant	Member of Technical Staff
Air Pollution Meteorologist	Network Analyst
Architect	Operations Research Analyst
Associate	Performance Analyst
Associate Consultant	Pre-Sales Consultant
Biostatistician	Programmer
Business Analyst	Project Scientist
CAD Engineer	Purchasing Agent
Consultant	Research Assistant
Contractor / Programmer	Research Associate
Cost Estimator	Research Mathematician
Cryptologic Mathematician	Research Mathematician
Customer Support Manager	Research Scientist
Data Processing Consultant	Research Statistician
Data Processing Consultant	Researcher / Software Design
Database Specialist	Section Supervisor
Developer	Senior Consultant
Field Inventory Asset Specialist	Senior Engineer
Financial Engineer	Senior Structure Engineer
Intelligence Application Officer	Software Analyst
Management Consultant	Software Engineering Manager
Manager of Financial Analysis	Staff Mathematician
Market Strategy Analyst	Statistician
Mathematical Software Programmer / Analyst	Support Scientist
Mathematical Statistician	Systems Analyst
Mathematician	Systems Engineer
	Technical Consultant
	Vice President

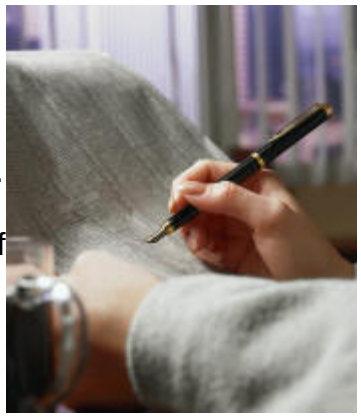
Motivation

You may be surprised to find that your reasons for studying mathematics -- because it is your best subject, because you find the subject content interesting, because it is challenging, etc. -- are motivations shared by those in the field.

Specialties

Some topics are more prevalent than others. Mathematical specialties include Modeling and Simulation, Numerical Methods/Analysis, Statistics, Probability, Engineering Analysis / Differential Equations, Operation Research, and Discrete Mathematics. This graph displays the percentage of mathematicians surveyed with Master's degrees or Ph.D.'s who mentioned mathematical specialties as a primary technical requirement of their positions; multiple mentions were allowed.

Career Path Forecast

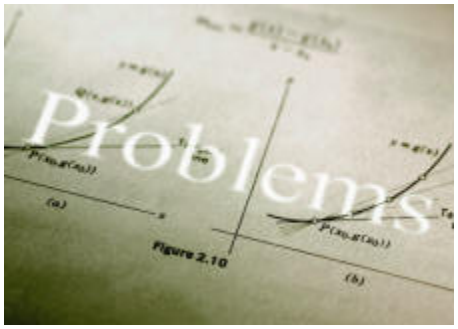


According to the U.S. Department of Labor, Bureau of Labor Statistics, employment of mathematicians is expected to grow as fast as the average. However, keen competition for jobs is expected. Employment of mathematicians is expected to increase by 10 percent during the 2006-16 decade, as fast as the average for all occupations.

Advancements in technology usually lead to expanding applications of mathematics, and more workers with knowledge of mathematics will be required in the future. However, jobs in industry and government often require advanced knowledge of related scientific disciplines in addition to mathematics. The most common fields in which mathematicians study and find work are computer science and software development, physics, engineering, and operations research. More mathematicians also are becoming involved in financial analysis.

Job competition will remain keen because employment in this occupation is relatively small and few new jobs are expected. Master's degree and Ph.D. holders with a strong background in mathematics and a related discipline, such as engineering or computer science, and who apply mathematical theory to real-world problems will have the best job prospects in related occupations. Holders of a master's degree in mathematics will face very strong competition for jobs in theoretical research. Because the number of Ph.D. degrees awarded in mathematics continues to exceed the number of available university positions -- especially those that are tenure tracked -- many graduates will need to find employment in industry and government. Additionally, employment in theoretical mathematical research is sensitive to general economic fluctuations and to changes in government spending. Job prospects will be greatly influenced by changes in public and private funding for research and development.

Professional Organizations



Professional societies provide an excellent means of keeping current and in touch with other professionals in the field. These groups can play a key role in your development and keep you abreast of what is happening in your field. Associations promote the interests of their members and provide a network of contacts that can help you find jobs and move your career forward. They can offer a variety of services including job referral services, continuing education courses, insurance, travel benefits, periodicals, and meeting and conference opportunities.

The following is a partial list of professional associations serving mathematicians and employers. A broad list of professional associations is available at www.careercornerstone.org.

American Mathematical Society

The American Mathematical Society was created to further mathematical research and scholarship. Founded in 1888, it now has approximately 30,000 members, including mathematicians throughout the United States and around the world. It continues to fulfill its mission with programs that promote mathematical research, increase the awareness of its value to society, and foster excellence in mathematics education.

Association for Women in Mathematics

The Association for Women in Mathematics is a non-profit organization founded in 1971 with a continuing goal to encourage women in the mathematical sciences. The organization sponsors a variety of programs and awards to encourage girls and women in the mathematical sciences. Among these is the Noether Lectures, which honors women who have made fundamental and sustained contributions to the mathematical sciences. Bonita Saunders, who is profiled in the Sloan Career Cornerstone Center is a recent honoree.

Mathematical Association of America

The Mathematical Association of America is the largest professional society of college and university mathematics teachers in the world. Today MAA's 30,000 members include college and university faculty, two-year college faculty, high school teachers, government and corporate workers, graduate school faculty, research mathematicians, and graduate and undergraduate students.

National Association of Mathematicians

The National Association of Mathematicians is a non-profit professional organization which has always had as its main objectives the promotion of excellence in the mathematical sciences and the promotion of the mathematical development of underrepresented American minorities. It also aims to address the issue of the serious under-representation of minorities in the workforce of mathematical scientists.

Society for Industrial and Applied Mathematics

The Society for Industrial and Applied Mathematics (SIAM) began in 1951 and now exists to ensure the strongest interactions between mathematics and other scientific and technological communities through membership activities, publication of journals and books, and conferences.