Mathematical Careers

Very few people seem to know the type of work mathematicians do in government and industry, and thus most people do not realize that mathematicians have wide employment opportunities beyond teaching. In fact, at Virginia Tech since 1995, about 78% of the mathematics graduates have gone into government or industry, whereas the remaining 22% have gone into middle and high school teaching. (Here we focus on students entering the workforce immediately after earning a B.S. Later we make some comments about graduate school.) Our students are hired to do applied mathematics. This applied mathematics is sometimes called engineering, sometimes called computer science, sometimes called actuarial science, etc. In fact, the resulting job title may not even mention mathematics. Every task, however, that you may encounter in a scientific career can be attacked in a mathematical manner - an approach that requires both mathematical competence and perspective. Companies and agencies know this to be true, and place considerable value on having employees who can master this approach.

The reason that companies hire mathematicians as well as particular types of scientists is that both groups have something important to contribute. Typically, companies will have people of various backgrounds (engineers, mathematicians, computer scientists, etc.) grouped together to work on pertinent problems. These real-world problems are "word problems," e.g., the group leader wants a quantitative analysis to streamline a procedure, to make it more cost-efficient, etc. This is the type of analysis that must precede actual computation, i.e., the group must determine formulas and equations that accurately describe the actual phenomena being analyzed. Clearly, if a formula for the solution already existed, it would be already programmed on the computer, and there would be no need to hire an engineer or a mathematician to punch a button and retrieve the answer.

The contributions expected from mathematicians involve logical organization and problem solving, as well as the use of higher-level mathematical tools to apply to problems. For example, students in, say, Operations Research, are often not required to take any mathematics beyond the sophomore year, whereas mathematics students take at least eight more courses. The mathematicians are able to bring to bear more powerful mathematics in their approach. They, on the other hand, are not able to take nearly as many specialized courses in the application area as do the majors in that area. Hence companies will hire both types of majors and have them pool their different talents. With this in mind, the mathematics curriculum at Virginia Tech places a heavy emphasis on career preparation. There are four different graduation paths (degree options) that allow mathematics students to focus more sharply on particular types of professions. (See the handbook on Mathematics at Virginia Tech.) All four options include required math-related courses that provide depth and breadth in applications areas. The career orientation in Mathematics at Virginia Tech is well recognized. The American Mathematical Society reported in 1999 that there were sixteen universities which averaged over 60 mathematics graduates per year. Virginia Tech was one of them and in the following six years has graduated 67, 72, 71, 80, 71, and 74 students; an average of 72.5.

A typical applied problem resolution involves three phases: (1) Build a mathematical model to describe the phenomena, (2) Analyze the model, and (3) Generate a computational approximation for the solution of the model. Building the mathematical model requires both knowledge of the science of the problem plus the knowledge of how to use mathematics to describe the phenomenum quantitatively. Analysis of the model involves, among other things, evaluating the accuracy of approximations used to make the mathematical formulation tractable. Finally, one must determine the best computational approach to get a reasonable solution with respect to the particular computer environment of one's workplace. Each of these three aspects is very mathematical in nature and underscores the need for mathematical competence. In fact, the computer revolution has increased, rather than decreased, the role of applied mathematics, because many complex mathematical models until recently were computationally intractable.

The bottom line, then, in choosing a career comes down to two essential items: (i) Taste and (ii) Talent. It is absolutely imperative for your own happiness and well-being that you choose an area of work that you enjoy and for which you have considerable aptitude. Too many students whose first love is mathematics turn away to a side area just because they are not aware of the fine career opportunities available in applied mathematics. Such students are making a serious mistake. Applied mathematical career opportunities are sufficiently comparable to those in other areas that you can comfortably base your decision on these two primary factors, taste and talent. To reinforce this concept, see the last page of this

brochure that gives a survey of job desirability for American workers. Note the six criteria on which the survey was based and also note that five of the top ten jobs are in application areas that mathematicians commonly select. Mathematician comes in at number eleven.

While in college you can use the Virginia Tech Career Services Office to obtain summer internships or to participate in the Cooperative Education Program. This work experience has three main advantages. First, you earn starting-level wages which is a big help in paying for your education. Second, you gain experience in the work place, on which company job interviewers place a high priority. Finally, you may find that the work is not the type you really want and you can then easily change the focus of your career. Temporary placement goes on throughout the year but the big event is the CONNECTIONS job fair in January for which Career Services arranges to have as many as 150 companies on campus for students to interview and present resumes.

You are, of course, already aware of the increasing need for mathematics teachers. This profession yields a wonderful way to combine a love of mathematics and a love of working with young people. Some of the other common occupations for mathematicians, which are much less well known, are the following.

ActuaryThe actuary deals in mathematical probabilities. He or she designs insurance and pension programs and analyzes and solves complex business and social problems. A large percentage of actuaries are employed in the insurance profession, but there are other areas of actuarial employment including consulting firms, state and local governments, banks, and academic institutions.

You do not need actuarial training to get a job in this field, but be prepared to invest many hours of concentrated study over several years to pass a series of nine or ten examinations given by the Society of Actuaries and the Casualty Actuarial Society. The actuarial societies have an immense amount of information in the following web site: http://www.beanactuary.org.

The Actuarial Societies want you to take calculus plus approved courses in Econ 2005 & 2006, Stat 3005 & 3006, and Corporate Finance. With this background in coursework, they then expect you to take Exam I/P in Probability. Next you should take Exam 2/FM in Financial Mathematics. Passing the first exam in college is a big step in getting hired. Passing the second exam, as well, will essentially make companies recruit you individually.

StatisticianStatisticians are hired by almost any business that hires engineers, computer programmers, economists, or mathematicians. Corporations that employ engineers or computer programmers, such as Norfolk Southern, hire statisticians. The statisticians have a strong programming background and work alongside engineers to help test equipment and current shipping methods. It is the statistician's responsibility to determine if the current methods are the most efficient. They also, on occasion, hire statisticians with a strong computer background to work with their overall shipping system - a major computer program which sends goods all over the country. Other businesses hire statisticians to work specifically with engineers to fit mathematical models to experimental data. In addition, statisticians are used to determine product safety and in quality control. Consulting firms which hire a large number of economists, hire many statisticians with a strong background in economics, or mathematics. For example, Booz-Allen & Hamilton hire a lot of people who are strong in any two of those three disciplines.

The largest employers in the U.S. and Canada for statisticians and mathematicians are the national governments. In many cases mathematicians and statisticians are considered to be interchangeable since many universities have joint math/stat programs. As a result, both mathematicians and statisticians are quite often hired for the same job and then specifically trained for that job. Nearly all departments of the U.S. government also hire statisticians to work solely on analyzing data.

Operations Research In some schools, operations research is taught as an area of applied mathematics. At Virginia Tech, it is taught in the Department of Industrial Systems and Engineering in the College of Engineering. In industrial engineering, one is concerned more with the overall picture and less with the details of a project. One might take a course, for example, in modeling, simulation and gaming. One is concerned with the design and management of production operations, and with the development of systems that assist management in the decision-making process. In a panel discussion at a meeting of the American

Mathematical Society, Dr. John McQuoun stated that, "The pressing problems in business, economics, and finance are under the heading of `management of systems,' for which no satisfactory theory exists. Man is not adapting today," he said, "and his understanding of modern institutions is desperately inadequate." The development of quantitative models to meet these challenges is a large mathematical undertaking.

Industrial engineering seems to be more engineering-oriented while operations research is more mathematics-oriented. In operations research, one is concerned with such concepts as maximization and mathematical models. Significant numbers of practicing operations-research analysts are trained (have at least one degree) as mathematicians and are quite successful in the field.

Most large corporations have operations research groups that are concerned with such parameters as costs, profits, and probabilities of various kinds of success or failure. You should have courses in probability and statistics, and you should be conversant with numerical analysis and computer methods. Furthermore, many smaller corporations, especially those performing quantitative studies and evaluations for federal government agencies, have a need for people with a sound math background. This type of company works in a variety of analytical areas and you may need courses in such areas as probability and statistics, physics, modeling, simulation, and operations research.

Computer-Oriented PositionsA math major with some computer science background is eligible for a wide variety of computer-oriented jobs, including systems analyst, programmer, data processing manager, and computer operations manager.

A systems analyst plans, helps design, and implements small- and large-scale computerized systems for a wide variety of business-oriented applications. A systems analyst might install systems in inventory control, purchasing, personnel, or truck-loading for a large company, or do systems planning for medical societies, municipal governments, and new town developers.

In the broader sense a systems analyst might not be concerned with the computer, although some computer background is helpful to communicate with the programmers. Courses in linear programming are helpful. Today's sophisticated industrial system needs to be balanced to make sure it is economically feasible. For example, how many of a certain style product should you produce to maximize profits. Every company with annual sales of over fifty million dollars has a computer-oriented cost system.

Courses in the following areas are recommended for students following this occupational strategy: Introductory and Intermediate Programming,, Data Structures, C++ and/or Java, Numerical Analysis, Computer Graphics, Scientific Computing, and Simulation and Modeling.

GovernmentA math major can qualify for Civil Service positions as a Mathematician, Oceanographer, Operations Research Analyst, Physicist, or Statistician. For the physicist position, you must have 24 semester hours of physics, but most mathematics majors should have the background to apply for the other positions listed.

A math major does not have to take the Federal entrance exam, but you must get on the Federal register to be eligible, except in a few exempt agencies. The largest employer of mathematicians from Virginia Tech has been the National Security Agency. Their main work, of course, lies in cryptography. Mathematicians work at many other government agencies as well, as you can see from the list of organizations which have recently hired Tech graduates on the next page.

Graduate School and Other Paths Virginia Tech mathematicians have taken jobs in many other areas, as well. A list of organizations that have hired Virginia Tech students in the last five years is given at the end of this brochure. About 12% of Virginia Tech mathematics students go on to do graduate work in mathematics or other technical fields. A list of graduate programs that have recently accepted Virginia Tech mathematicians is also given at the end of this brochure.

You may not realize that graduate school in mathematics, the sciences, and engineering is often "free." Employed as teaching assistants or research assistants, graduate students can have their tuition paid and

receive a stipend that covers most living expenses. A graduate degree (either M.S. or Ph.D.) increases opportunities in the areas described in this brochure and creates opportunities in research as well as in college and university teaching.

The January 23, 2006 issue of Business Week has an article entitled "MATH {will rock your world}." It describes how mathematicians are increasingly becoming a new global elite in businesses because they can take the vast amounts of data and analyze it. "The flow of data is growing faster than the processing power to crunch it. To winnow it down, we must come up with exponentially better algorithms." Some examples given are: IBM builds math profiles of 50,000 consultants so that computers can pick the perfect team for every assignment; National Security Agency builds algorithms to trawl Internet and phone traffic looking for patterns in speech, subject and frequency that might point to the next attack of terrorists; Enologix, a California Consultancy, uses algorithms to cull a database of 70,000 wines and runs analyses to help vintners mimic the chemistry of wines ranked highly by a leading critic; Efficient Frontier, a Silicon Valley startup provides mathematical optimization for online ad campaigns.

You can get more information about mathematical careers from the Mathematical Association of America. (http://www.maa.org/students/undergrad/career.html), the American Mathematical Society (http://www.ams.org/careers/ , http://www.ams.org/early-careers/, andhttp://www.ams.org/employment), and the Society for Industrial and Applied Mathematics (http://www.siam.org/careers/).

Organizations that Have Recently Hired Virginia Tech Mathematicians: American Power Conversion, Booz Allen Hamilton, Cintas Corporation, Department of Defense, Ferguson Enterprizes, File Link Business Systems, Inc., IBM, Internal Revenue Service, MCR Federal, Mercer Human Resources, NASA Goddard, National Instruments, National Security Agency, Northrop Grumman, Nuclear Regulatory Commission, Raytheon, Recognition Research Inc., Science Applications International Corp, Tecolote Research, US Air Force, US Census Bureau, US Navy, Virginia Tech Transportation Institute.

Graduate Schools of Recent Graduates Duke University (Mathematics)
George Washington University
Louisiana State University (Mathematics)
MIT (Physics)
McMaster University (Mathematics)
Oxford University (Philosophy)
Princeton University (Physics)
Stanford (Mathematics)
University of California (Engineering)
University of California (Interdisciplinary Program)
University of Chicago (Social Sciences)
University of Georgia (Mathematics)
University of NC (Computer Science)
University of Tennessee (Statistics)
University of Virginia (Classical Languages)
University of Virginia (Economics)
University of Virginia (Mathematics)
University of Wisconsin (Economics)
Virginia Tech (Computer Science)
Virginia Tech (Education)
Virginia Tech (Engineering)
Virginia Tech (Latin American Studies)
Virginia Tech (Mathematics)
Virginia Tech (Statistics)

JOBS RATED ALMANAC*Overall Rankings 2002 Study--250 Jobs Ranked by Cumulative Scores
In the overall ranking system, it is assumed that each of the six factors - Environment, Outlook, Stress, Security, Physical Demands and Income - is equally important. Scores are derived by adding together the individual ranks that each job has previously received. Because a high rank (i.e. 1 or 2) in an individual category means it is more desirable than a low rank (i.e. 249 or 150), the cumulative scoring method used below translates to the lower overall score achieving the highest rank in the overall rankings.

The overall winner by this ranking method is biologist, which received 115 ranking points (the total of 1 point for its environment rank, 25 point for its income rank and so on). The overall loser is lumberjack which received 1,415 points out of a possible 1,500.

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