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Scope of Study: This report has been prepared to help the student, teacher, parent, or anyone who is interested in career guidance in mathematics in order that they might have at hand: (1) a brief summary of the importance of mathematics to everyone; (2) some of the major occupations employing young people with good mathematical backgrounds; and (3) a summary of what one may expect to find in courses which deal with so-called ''modern mathematics'', which is just beginning to have a great impact on the high school.

Findings and Conclusions: Mathematics and the way of thinking out a problem it teaches are essential for anyone in any kind of work and knowing what mathematics can do is a great help in business or any other career.

Mathematics is no longer considered to be merely a tool for such fields as engineering and physics, but has come into its own as a field of endeavor. Mathematics majors may now find employment as statisticians, members of operations research teams in industry or government, actuaries, and high school and college teachers where the work requires primarily a sound background in mathematics as a prerequisite for success and future advancement.

The mathematics curriculum in the high school is undergoing a change in order to meet the needs of the high school student. There is some new subject matter but, more important perhaps, is the point of view from which both the old and new subject matter will be approached. This is the reason for its being called ''modern mathematics.''

ADVISOR'S APPROVAL James H. Zant

CAREER OPPORTUNITIES IN MATHEMATICS

By

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CAREER OPPORTUNITIES IN MATHEMATICS

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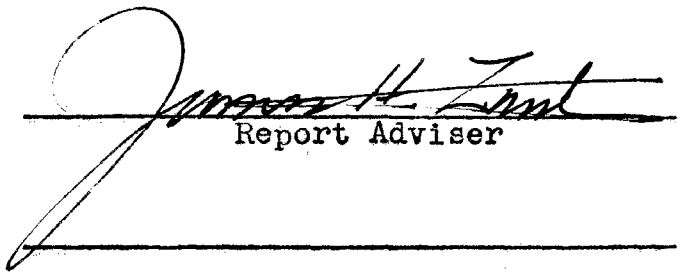

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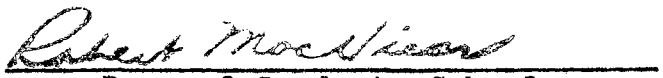

Dean of Graduate School

PREFACE

In today's modern, highly-technical society mathematics has attained an important, recognized position as the foundation of most of the sciences. In recent years attempts have been made to apply it to the Social Sciences as well. The result has been an increased demand for mathematicians from the training of B.A. to Ph.D.

The author has found from his own experience that the student and his guidance teacher as well, if the school has one, are often unaware of the vast strides which mathematics has made as a field of endeavor in its own right in the past two decades.

Thus this report has been prepared to help the student, teacher, parent, or anyone who is interested in career guidance in mathematics in order that they might have at hand: (1) a brief summary of the importance of mathematics to everyone; (2) some of the major occupations employing young people with good mathematical backgrounds; and (3) a summary of what one may expect to find in courses which deal with so-called "modern mathematics", which is just beginning to have a great impact on the high school math curriculum. The writer has limited himself primarily to those occupations which require college undergraduate and graduate work in mathematics in order that the information given be more encompassing for

those listed. Occupational opportunities requiring only high school mathematics are so numerous and varied that one could write a good-sized book on them; hence the limit mentioned above was thought to be desirable.

The writer wishes to express his appreciation and gratitude to Dr. James H. Zant, Director of Supplementary Training Program for High School Science and Mathematics Teachers of the National Science Foundation, for his helpful guidance, suggestions, and use of his supplementary materials in the preparation of this report.

Gratitude is also expressed to my wife, Ruth Ann Brubaker, for her encouragement and also her patience in typing this report.

This report is dedicated to my three children, Jayne, Darlene, and David, who, in a few short years, will experience the problems of our complex society. May they realize, however, the impact which mathematics has had on our society and enjoy the benefits thereof.

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CHAPTER I

INTRODUCTION

''What can I do with mathematics?'' ''What vocations require mathematical backgrounds?'' These questions arise many times in the minds of youths taking their first course of high school mathematics and the time to answer the question is right then and there, not one or two or even four years later.

In his brief experience as a teacher thus far, the author has found that many high school students and their parents realize the necessity for studying mathematics but they know of very few occupational opportunities, other than the various fields of engineering, in which a knowledge of mathematics is desirable or necessary. While these careers do require a knowledge of mathematics, they are by no means the only, or perhaps, even the most important ones, from a mathematical standpoint.

Even though a student does not plan to go to college or, if he does, does not plan to study mathematics or the sciences, high school mathematics will never come amiss. Remember this: Mathematics and the way of thinking out a problem it teaches are essential for many different kinds of work in our technical age. Always needed by scientists and engineers, mathematical training is now becoming more and more

important in the social sciences and in business. A department store used to guess how much merchandise to keep on hand to get the most profitable results; now it can hire an ''operations research'' specialist to make a mathematical analysis to decide the question. Factories which used to inspect every item that came off the assembly line can now use statistical ''quality control'' methods and save a lot of money. Even if you don't become an engineer or a statistician, knowing what mathematics can do will be a great help in business or any other career.[1]

Now, back to the student who thinks he might choose mathematics as a career. For those who do so, it is important to point out that high school and early college undergraduate mathematics, with its emphasis on problem solving, is quite different from the pure mathematics studied in a university and pursued by research workers who are professors at universities. This later mathematics is largely concerned with logic and abstract ideas; and the solution of problems plays a minor part. People of real stature in this kind of mathematical research find their place as professors at our great universities; for it is in teaching particularly that advancement to the highest levels requires distinguished performance in research.[2]

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[1] Mathematics and Your Career, U.S. Department of Labor, Bureau of Labor Statistics.

[2] Professional Opportunities in Mathematics, The Mathematical Association of America, University of Buffalo, July, 1959, p. 2.

For people with less creative talent, there are many opportunities for interesting and rewarding work in teaching on the high school and college level. Also for the college graduate with a bachelor's degree in mathematics, it will be seen that there are many professional opportunities in industrial and governmental positions.

In passing, it might be well at this point to stress the importance of college training in other fields related to mathematics. The mathematician, to be effective in industry, government, or university, must be a well-rounded person. While courses in analytic geometry, calculus, and differential equations constitute a common mathematical background of all scientists and engineers, a selection of courses from physics, chemistry, engineering, biology, psychology, statistics, and economics will usually be necessary to make the mathematician effective in applied work. In industry and government the scientist and the engineer work in close cooperation; in actuarial work, and in many fields which offer jobs to young people with statistical training, a sound background in economics is of great value.[3]

The purpose of this report is to give the student an opportunity to read and compare the newer, as well as the older, career opportunities available in mathematics.

It presupposes that the student will take all the mathematics offered in his high school, therefore eliminating

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[3]Ibid, p.3.

the need for "make-up" courses in college. Only by strengthening his mathematical background in high school can the student expect to take the college mathematics courses required for a given field and do well in them. The need for a strong background cannot be overemphasized.

The author has also endeavored to show the recent increase of opportunities for women in mathematical careers by including a section just for them.

In order that the beginning high school student and his parents may realize that a change is taking place in high school mathematics content, the author has included a chapter on modern mathematics and some of the changes it will bring about.

In each part, the character of the work is described and a few suggestions are given as to the college courses the student would find helpful in preparing himself for that field. In most cases the author has purposefully left out discussion of salaries because they vary so widely from area to area and year to year. One can be sure, however, that the salaries are gratifying due to the demand for such people.

The bibliography at the end of this report lists materials the author found helpful, which might also aid the student if he wishes further information.

CHAPTER II

CAREER OPPORTUNITIES

Part I: Opportunities in Mathematical and Applied Statistics

Statistics is one of the newer fields of mathematics and has received much attention in this country during the last 25 years, although it has been developing in Europe for over a century.

It deals with the mathematical examination and study of various kinds of problems involving the collection and classification of data which arise in scientific research, in social and economic investigations (you have probably heard of the Gallup Poll, especially at election time), in business and industry (you have no doubt heard of "quality control" in automobile factories in which at certain intervals of time they test an item taken from the assembly line), and in government work.

Statisticians can be divided into two classes. The first is the class of mathematical statisticians who deal with the theory of statistical formulas and methods, testing hypotheses and estimating unknown quantities according to the terms of probability. They also work out methods of applying these theories. The second class of statisticians includes those who apply the statistical methods already known in a given

field. Sometimes a person can be placed in both classes if he is an expert in some field where statistics can be applied and has had enough statistical training to be able to use it.

Mathematical statisticians need a considerable amount of advanced mathematics. Requirements include real and complex variables, linear and quadratic forms and matrix algebra, n-dimensional Euclidean geometry, and measure and integration theory. These subjects are essential for a thorough understanding of probability, which is the basis for mathematical statistics, and in order to understand them, the student must include a strong group of undergraduate courses in mathematics at least through the Calculus.

The training of the applied statistician includes basic courses in statistics together with the training in the field in which he intends to apply his statistics. Courses in applied statistics beyond the usual introductory courses in statistics include analysis of variance, design of experiments, quality control and engineering statistics, biometry, survey sampling and its applications, economic statistics, and psychometrics. The student would not take all of these since they apply to many different fields but would take only those which are allied to his field of application.

Many universities now offer courses involving applied statistics, but fewer offer courses in mathematical statistics because they cannot find qualified personnel to teach them, with the result that this is one wide-open field for interested students who are able to obtain the

Ph.D. degree.

The demand for statisticians is great because it is a comparatively new field and has undergone tremendous growth due to interest in statistical methods in industrial quality control, design of experiments in industrial research and development, research in the biological sciences, collection and analyses of government statistics, market research and commercial sample surveys, and psychological testing.

Of all these fields, industrial quality control has grown the fastest. In any mass-production set up, quality control has been one of many innovations used to maintain uniform quality of the thousands of kinds of pieces of equipment used. The Bell Telephone Company has used it for the last 25 years and the auto-makers have been using it since World War II.

Quality control personnel need one or two courses in engineering statistics in addition to usual chemical, electrical, and mechanical engineering courses to meet the needs of statistical quality control work.

Statistics has long been used in business operations. Sampling methods are used to obtain information on the buying and reading habits of the public at large by taking surveys over certain small areas all over the country. You are no doubt aware of the TV ''ratings'' which are the result of this sort of sampling. Statisticians with training in economics and the social sciences and in the applications of sampling are being sought for this kind of work.

Part II. The Mathematician In Operations Research and Industry

Since a time just prior to World War II, attempts have been made to provide a scientific basis for operations and management decisions. It has come to be called ''Operations Research'' and in many industries mathematicians are working in so-called industrial laboratories.

In industry problems of plant control, production scheduling, distribution, sales promotion, and advertizing, and even some broader policy questions have been studied by operations research teams.

In military operations, operations research has been used in devising bombing patterns, developing tactics for submarine warfare, scheduling airplanes or oil tankers, and incorporating new inventions such as radar into effective operational employment.

The mathematician plays an important role in trying to obtain numerical solutions to equations of many types and working on the development of mathematical models to explain the structure of these industrial and military operations.

An industrial mathematician in the industrial laboratory is working in the ''big leagues''. At the top level, he will primarily be a problem formulator or in other words, he must create the problem in workable mathematical form. He

thus must have a research training in pure or applied mathematics, as broad a background as possible, and above all else, he must have an interest in the other man's problems - as wholes, not just their mathematical aspects.[4] He will be doing creative research which can be compared to the university Ph.D. who is doing academic research. Indeed, the industrial mathematician of this type must have a Ph.D.

Other industrial mathematicians may find that they must solve as well as formulate problems which are of a difficult type.

For those who do not wish to do creative research or obtain a Ph.D. to enable them to do creative research, there are many opportunities for problem-solvers or computers who do routine computing, sometimes with the aid of computers and sometimes by the usual mathematical tools or manipulations.

In addition to the fundamental courses of algebra, trigonometry, and the elements of calculus, the industrial mathematician should have advanced courses, such as linear differential equations with constant coefficients, theory of functions of a complex variable, and partial differential equations and their solutions in terms of orthogonal functions, such as Bessel functions and Legendre functions. To these may be added Fourier and Laplace transforms, matrix algebra, and Boolean algebra.

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[4] J. W. Tukey, "Mathematical Consultants, Computational Mathematics and Mathematical Engineering," American Mathematical Monthly, 62 (1955), 565-571.

It might be well to mention here that many industries have adopted the philosophy that the more a person knows, the more valuable he is, with the result that those who show promise can acquire advanced training either while on the job or at a university which offers the desired material. And the nice part about it is the fact that the person is considered to be on the payroll and therefore is still able to support himself and/or his family, too.

Today, no mention of mathematical opportunities in industry or operations research would be complete without proper attention to electronic computers and data processing machines and the influence they have had and are having on industry, military operations, and mathematics.

Many people have the impression that the computer will take a little information which someone ''feeds'' to it and then give out ''world-shattering'' results. This is not true. They are capable of performing remarkable feats, with great speed and accuracy; but they must be told, in the greatest detail, exactly what they are to do.

The newer computers have ''memories'' with the result that all the operations which are to be fed into the computer must be analyzed and complete instructions given to the machine before it can come up with the answer. This is called linear programming.

Some of the characteristics of digital computers which might be of interest are:

1. They will perform multiplication at speeds some-

times as fast as 30 millionths of a second.

2. They have internal memories sometimes of several thousand words (either numbers or instructions), and external memories many times as large.
3. They are able to follow instructions in succession, and set up automatically the proper connections between machine parts.
4. If, at any point in the calculation, there are two or more alternative courses for the next operation, they will select and perform the correct one according to the conditions specified in the instructions.[5]

Can you see now why they are called "mechanical brains"?

The acceptance of computers came during the Second World War in the field of ballistics which is the study of trajectories or paths of bullets, bombs, etc. Many complex formulas were needed in a short time and computers were able to supply them.

After the war, a few enlightened men came to see the importance of computers in solving complex scientific problems and others saw changes that might be introduced into industry.

The field of digital computers has taken great strides in the past fifteen years. The widespread availability of these machines is having a broad impact on applied mathematics

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[5]Mina Rees: "Digital Computers", American Mathematical Monthly, 62 (1955), 414-423.

and a great many mathematics graduates are finding employment in computing laboratories attached to industrial and government establishments.[6] J. W. Tukey even goes so far as to suggest that if the colleges are to meet the needs of industry with respect to men trained for computer work, then a new field of applied mathematics must be introduced which will lead to degrees in what he chooses to call ''mathematical'' or ''computational'' engineering.[7]

A computer requires many men for its operation. Of some of the more recent computers, it is estimated conservatively that a staff of at least thirty persons per machine is needed. Over 90% of these people must possess A.B.'s or M.A.'s in mathematics and their work as coders and lower level problem analysts is high-level routine which requires a solid grasp of a substantial amount of mathematics. The mathematics would be of the same nature as mentioned previously for industrial engineers.

Some universities are now offering courses in computer programming and techniques for mathematics majors who wish to work with computers in industry.

Part III. Mathematicians In Government

The government, like industry, has its laboratories where it carries on research and much that was said of math-

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[6] Rees, p. 11.

[7] Tukey, p. 9.

ematicians in industrial laboratories can be applied here. The essential differences are that, as an employee of the government, the mathematician has a civil service position, and that he has a greater variety of opportunity since the total spread of government is so broad. Also it should be mentioned that many jobs are of an administrative nature.

Each year the government invests heavily in research carried on at universities or by industries. Much of this work is under contract to the Department of Defense. In the university, such research is usually carried on in a specially constituted part of the university by persons having no teaching assignments; there are often openings for junior persons who are interested in applying their mathematics to military and other problems of interest to the government and who may spend part of their time in graduate study. A few industrial laboratories have been set up for the same purpose.

Most people entering governmental service in mathematics can expect their work to be of a computational nature and thus require a minimum of mathematical judgment. The usual courses through differential equations and some work in mathematical statistics are desirable.

If more experience and training are acquired, especially training in some field of physical science or engineering as well as mathematics, the government mathematician can rise to positions in higher grades under the Civil Service plan. As in the field of teaching, which is taken up in another

part of this chapter, there are many opportunities for younger workers to obtain in-service training, which will enable them to advance to more desirable positions.

If the student wishes to learn more about the Civil Service program, he should see his guidance counselor or write to the Regional Civil Service Office nearest his community.

Part IV. Opportunities for Mathematicians In The Actuarial Profession

The actuarial profession is perhaps the most difficult mathematical career in terms of qualities required for success. In the words of an individual already in the profession, an actuary must possess competent statistical and mathematical capacity, adequate economic and financial knowledge, and wide social information. The successful actuary has been further described as a person with a determined, lively and ingenious mind and a broad outlook. The reason for adding a separate section for the actuarial profession rather than including it in the section on statistical career opportunities is evident, I believe, because this profession requires so much more than just a sound mathematical background. Indeed, the student will usually not need mathematics beyond the calculus, but all of his work will require the exercise of reasoning and judgment similar to that used in his study of mathematics.

The actuary of a life insurance company is responsible

for calculating the rates his company charges and for preparing the tables of death rates upon which such calculations are based. He also determines the benefits which the company offers on its various types of policies and how much money must be set aside to assure payment of these benefits when they must be paid. He investigates the effects of various physical impairments, occupational hazards and other unusual risks upon death rates. He also works with the company's medical officer in determining whether to accept or reject applicants for insurance. In recent years the actuary has helped develop the new group insurance and pension plans which are a part of the so-called ''fringe benefits'' in many factories and businesses.

The casualty or fire actuary does the same things for this type of company. Since these types of insurance are revised annually, the actuary in this field spends most of his time on the investigation of current experience and the calculation of rates.

There are actuarial positions in many of the state insurance departments, which supervise and regulate the insurance business. The Federal governments of both the United States and Canada use actuaries in several departments, such as the Social Security Board, the Veterans Administration, the Railroad Retirement Board, and the Bureau of the Census.

An actuary may be independent and act as a consultant for several firms which are not large enough to afford a full-time actuary.

If the student wishes, he can obtain some ideas of the scope of the actuary's work by consulting recent issues of the Transactions of the Society of Actuaries and Proceedings of the Casualty Actuarial Society. They are available at many college libraries and offices of insurance companies.

Since the insurance business has grown by leaps and bounds with the formation of many new companies and expansion of older companies, the actuarial profession is not crowded and there appears to be no prospect of its becoming so for many years.

The training of an actuary is rugged. Professional status can be attained only by becoming a Fellow in either the Society of Actuaries or the Casualty Actuarial Society.

To become a Fellow in the Society of Actuaries one must pass nine examinations set by the Society and given annually. The first three of these, known as preliminary examinations, consist of:

1. a language aptitude examination
2. a general mathematics examination covering algebra, trigonometry, analytical geometry, and calculus, and
3. an examination covering probability and statistics.

The remaining six examinations which are more advanced in character, cover such topics as finite differences, construction of mortality tables and monetary tables, selection of risks, calculation of insurance premiums, investments, the equitable allocation of dividends, life insurance

accounting, life insurance law, group insurance, social insurance, and pension plans. Upon completion of the first six examinations, the student becomes an Associate of the Society of Actuaries, and upon completion of all nine of the examinations he becomes a Fellow.

Depending upon the student and the amount of time he devotes to study, it will take from four to ten years to complete the examinations. They are exacting and difficult, and becoming a Fellow is about equivalent to obtaining the Ph.D. The first three tests are best taken while the student is in college. The rest can be taken while he is employed in some actuarial capacity, since practical experience is valuable, indeed, essential in preparing for these examinations. Some of the larger insurance companies will hire promising actuarial students, give them experience in many departments while they are studying for the examinations and give them automatic pay raises as they pass them.

Professional status as a casualty actuary is obtained by becoming a Fellow of the Casualty Actuarial Society. The usual method is to pass their battery of examinations of which there are eight. Many of the casualty companies hire college graduates as actuarial students although they do not have formal training programs.

As mentioned earlier, college mathematics courses beyond the calculus are not necessary for the actuarial student. Courses in mathematical statistics should be taken if possible. Some schools of higher education are adding

courses in undergraduate and graduate work in actuarial science.

A thorough understanding of English composition is essential. A full year's course in economics, some accounting, and a course in banking and finance will be useful.

Any other courses the student takes should be aimed at broadening his cultural background.

For information about the preliminary actuarial examinations, the student should send for the booklet, Preliminary Actuarial Examinations, published by the Society of Actuaries, 208 South LaSalle Street, Chicago 4, Illinois. Information about the examinations of the Casualty Actuarial Society can be obtained by addressing the Secretary-Treasurer of the Society at 200 East 42nd Street, New York 17, New York.

The student can best learn about the training programs and actuarial student opportunities offered by the insurance companies by writing directly to the companies in which he is interested.

Part V. The High School and College Teacher of Mathematics

As in the case of other career opportunities in mathematics, the teaching field is not crowded. In the years ahead, with college enrollments expected to double, the demand for well-trained mathematics instructors and professors is expected to far exceed the supply.

Whenever teaching is mentioned, a person usually gets around to the topic of salaries. While it is true that

the schools usually cannot match the salaries in many of the areas mentioned earlier in this chapter, it can be said that they are improving and when one remembers that the school year is only nine or ten months long, the salary does not appear quite so bad. In reasonably good times a good mathematics teacher can often find attractive summer employment with a business or industrial firm to supplement his income. Also, in recent years and in the years to come, mathematics teachers can apply for summer institutes sponsored by the National Science Foundation which enable the teacher to not only earn extra hours of mathematics credit, but also be paid quite well for it at the same time.

The teaching system in most states allows for a certain measure of security because of laws of tenure which require that a school board have very serious, specific reasons for dismissing a teacher. In many states, a pension system has been formed which is far superior to that of social security and can be maintained by the teacher at a smaller cost than those plans offered by insurance companies because school boards match or exceed the amount invested by the teacher himself.

It might be mentioned here that if the student thinks he might like working with young people with whom there's never a dull moment, then by all means, he should consider teaching as a career. There is much satisfaction in seeing young people mature mentally and go on to greater heights perhaps through your efforts as a teacher.

The mathematics curriculum is in a period of modernization and new teachers in the field will have much to do with the success of the program. This also adds interest; for it is always intriguing to try something new and see the results of such efforts. The search for ways in which films and television can be used to improve mathematics instruction offers still another challenge to the mathematics teacher.

Teaching requires a broad background, much as does the actuarial profession. Usually a teacher will prepare quite well in one field called his major and reasonably well in one or two other fields, called his minors.

The mathematics major usually takes college algebra, trigonometry, analytical geometry, calculus, differential equations, and modern algebra. Courses in projective geometry and non-Euclidean geometry should also be included to get a broader outlook and appreciation of geometry.

The junior college, college, or university teacher will be expected, as a general rule, to have a Ph.D. or at least be working on it. He should have a thorough knowledge or background in the disciplines of analysis, geometry, and algebra; and he should have an understanding of their relations to other subjects as well.

The high school teacher of mathematics has the responsibility of introducing the student to mathematics, which involves problem solving, beyond arithmetic and of creating a taste for or delight in the subject. The college teacher then has the responsibility of training these students to

undertake the careers mentioned in this chapter. He also will teach students of the natural sciences and engineering who look upon mathematics as a tool.

The college teacher is often expected to further the knowledge in his field by doing research. In a smaller college, this will be a minor part of his endeavor, but in the university, this may be his major task. He may also guide graduate students in their research work.

College or university professors are perhaps more underpaid than high school teachers when the education requirement is considered. However, they enjoy the pleasures and advantages of an academic life and they will have the security that is afforded by tenure rules and pension plans.

Part VI. Opportunities for Women in Mathematics

In the field of mathematics, as in many other fields of endeavor today, women are finding themselves accepted on a level almost comparable to men in many cases. They have proven their ability to handle almost all types of problems and find ready employment as problem solvers or computers.

High school teaching is the most likely field in which women mathematicians are accepted on an equal basis with men. The salaries are the same regardless of sex. Opportunities are available for women college teachers, but few are actually filled.

There are probably more opportunities in business and

government for women with mathematical training than there are in college and university teaching. If their training is in statistics, they are usually assured of employment; for women are readily accepted in this field as witnessed by the fact that about 10 per cent of the members of the American Statistical Association are women. Industrial laboratories usually employ only women to fill positions in their computing groups.

In government there also are many women in the lowest levels, where the emphasis is on computing under relatively close supervision. In the higher levels, because it is relatively hard to secure a well-qualified mathematician for many government positions, the head of agencies usually welcome women especially if their qualifications are much better than those of the available men. Sometimes heads of governmental departments, as well as businessmen, hesitate to employ women except for the lowest level positions, but once a woman proves herself and is established in a higher position, she is usually fully accepted.

The actuarial profession has accepted women into its ranks and some of them have attained prominence. Any limitations in opportunities has been due to the reluctance of insurance companies to assign women to executive duties and to positions requiring outside contacts.

Women mathematicians then can expect to find ready employment in routine mathematical work if they have a B.A. or M.A., but will find that the top positions will be

much more difficult to attain because of the keen competition with men and the reluctance of employers to hire them.

CHAPTER III

MODERN MATHEMATICS, WHAT IS IT?

Much mathematics taught in the high schools today is the same as has been taught for 200, yes, even 2000 years, and is referred to as ''classical mathematics''. While other courses have undergone changes to keep in step with the times, mathematics, until very recently, has remained the same for the simple reason that most people studying mathematics eventually proceeded to teach it and so the process went generation after generation.

Within the past fifteen to twenty years, however, young mathematicians have found new opportunities mentioned in the previous chapter with the result that they ''mingled with the crowd'', so to speak, and found their backgrounds sadly out of date; for mathematicians pursued the new ideas with single-minded devotion; the teachers concentrated on the reformation and presentation of the old ideas, and there was no exchange of interests. With the world situation pointing up the need for national security and an increase in technology, which in turn increased the need for more and better-trained mathematicians and scientists, the colleges and universities began to offer new courses with many new concepts in mathematics such as algebraic topology, group theory, the theory of sets, game theory, point set and

combinatorial topology, the theory of matrices, abstract algebra, and many others which, collectively, have been called ''modern mathematics''. Most of these new concepts are now taught in our colleges and universities. Within the next five to ten years, at least an introduction to these concepts must and will be offered at the high school level, if the mathematics program is to meet the needs of the students, particularly those who expect to take some college mathematics.

Some people in the field, for example, Albert E. Meder, Jr., also consider ''modern mathematics'' as being a new point of view as well as containing new subject matter content since much of the classical mathematics is still involved.[8] Mathematics is one of those subjects which builds upon its past and nothing is discarded.

This is perhaps the best over-all way of looking at modern mathematics on the high school level, that is, that it is a new point of view as well as new subject matter.

Some of the new ideas which will be taught in algebra include such things as modulo numbers in which addition is not the usual addition, but has the same properties. Most readers will be familiar with the clock, so let's use that as an example. A new number system can be made using only the numbers of a clock. It is called ''modulo 12''. Suppose

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[8] Albert E. Meder, Jr.: ''Modern Mathematics and Its Place in the Secondary School'', Mathematics Teacher, vol. 50(1957) pp. 418-423.

you were asked to add "11 + 7". The first answer that usually pops into one's head is "18", but remember that our number system only goes from 0 to 11. Here's where our knowledge of time and use of the clock comes in handy. If it is 11 o'clock and you work for 7 hours, you know that you quit at 6 o'clock. Therfore, 11 + 7 = 6 in our new number system. Perhaps you may wish to play around with this number system by constructing a table. Such a table may be constructed for multiplication, also. Watch your step, though. Remember no number beyond 11 exists. Examples are 2 · 2 is 4, 4 · 3 is 0, 4 · 4 is 4, etc.

Our number system is called a number system to the base 10 since we use ten digits (0, 1, 2, 3, ... 9). An interesting system is one which is to the base 2 containing only the symbols 0 and 1. Our numbers are then 1, 10, 11, 100, 101 instead of 1, 2, 3, 4, 5, etc. The number 1011 will mean: $1011=2^3$ + 2 + 1 or eleven, in the ordinary notation. This system seems strange and perhaps a little silly but its application to computers has had a profound impact on mathematics as mentioned in Chapter Two. This method of counting is necessary because computers count on electrical relays which have only two fingers 'off' and 'on'.[9]

This is only one of the new concepts and an application.

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[9]Saunders MacLane: "The Impact of Modern Mathematics On Secondary Schools", Mathematics Teacher, vol. 49,(1956) pp. 66-69.
Also James H. Zant: "The Mathematics and Science Teacher of Tomorrow", Mathematics Teacher, vol. 50(1957) pp. 426-431.

There are other concepts, both old and new, which will be included, such as, the study of inequalities and expressions involving the concept of absolute value, the properties (commutative, associative and distributive) of numbers, the real number line,order, and the coordinate system as used in graphing. All these concepts point up the idea that the ''new'' algebra will be a study of mathematical structure.

For the first time since the advent of the curriculum in mathematics as we now know it, algebra taught in the freshman year will become a useful tool in geometry taught in the tenth grade. The course will include some study of solid geometry since it (solid geometry) will not be taught as a separate subject anymore. There will also be an introduction to analytic geometry which is the study of geometry on a coordinate system or, in other words, geometry from a graphical standpoint.

Euclidean geometry is still present with many of its proofs, but the postulates, theorems, and axioms will be more precise and logically presented.

Some attempt may also be made to obtain an appreciation by the student that spaces and geometries of the utmost variety and character are possible and useful. Most high school students are aware of what we call three dimensional space - a box, for example, has length, width, and height. However, what most students aren't aware of is the fact that there are other dimensions such as time, speed, etc. This idea leads to a variety of new concepts in geometry

with which the student should become familiar.

The eleventh grade course will contain much intermediate algebra and trigonometry since these two courses, as such, will be revised and parts of each course discarded. The student will learn more about number systems, particularly our own. Analytic geometry will be investigated farther than in geometry. The concepts of function, complex numbers, mathematical induction, and logarithms will be introduced and studied.

The fourth year course is the most flexible course of the whole group.

The first semester will usually be a further study of polynomials as functions and also trigonometric, exponential, and logarithmic functions.

In the fourth year, there will be the further development of the notion of sets and their operations. There will be an increase in the amount of time and material devoted to probability and statistical inference since one of the most significant advances in mathematical research is that mathematics can now be applied to phenomena in which chance plays a role.

Perhaps the most important idea to be incorporated in the new mathematics curriculum at all grade levels is the notion of <u>set</u>; important because it has applications in all branches of mathematics and even to various social studies. A set is really nothing more than an arbitrary collection; finite or infinite, of things. There is a definite vocab-

ulary associated with sets. For example, the ''intersection'' of two sets is their common part; the ''union'' of two sets is the set including everything in both the original sets; and the ''complement'' of a set is everything in the larger set that is not in the smaller. With the words described above and their appropriate symbolism plus many others not mentioned, we have what is called an algebra of sets.

The elementary notions of set will be introduced at the freshman level, or even lower, and developed further in senior courses.

Most of the ideas mentioned above has come from the material incorporated into the texts of the School Mathematics Study Group. These texts are being used on an experimental basis in many schools at the present time. While the material may vary somewhat in texts offered by other groups, the same fundamental ideas and concepts of modern mathematics will still be present.

Modern mathematics can be said to be the mathematics which mathematicians of today are using. Since nothing in mathematics is ever lost or becomes unimportant, the student will find that the high school mathematics curriculum will include many new ideas and approaches, but still contain much of the old, thus enabling it to be fully relevant to the modern world.

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