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CONTENTS

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A PETITION

TO ALL CHAPTERS SECRETARIES, INITIATES, MEMBERS AND SUBSCRIBERS

We, your new editors, of the Journal seek the help of all chapter secretaries, initiates, members and subscribers to improve the Journal. We want all to take a personal interest in what we are trying to do and any criticism you wish to make will be most welcome. When we took over the Journal from the former editors, we found practically no backlog of material for coming issues. We learned from the former editors that this condition plagued them throughout their term. In order to correct this condition, we petition all readers to help in building up a reserve of expository papers, elementary research papers and papers exhibiting new methods to old problems.

How can you help? Any paper of which you know and think might be of interest to our readers, see that the author submits it to us for review. All chapter advisers should encourage student members of their chapters to prepare papers which they give before their chapters and submit them to us. We would like to have papers contributed by all chapters. Let us make this Journal a truly representative publication in which all chapters are represented through contributed papers.

We have instituted a permanent book review section and solicit people to volunteer in reviewing books which are submitted.

Also a new division of the Journal entitled "News and Notices" is being introduced. We solicit pertinent news concerning our members. If you want us to publish anything of interest concerning you, please, feel free to send it to us.

Another new division of the Journal is being instituted for the first time in this issue entitled "Operations Unlimited."

We wish to thank all of you who take this petition seriously and who will lend their support to us in making this publication one which this great Fraternity will be forever proud.

The Editors

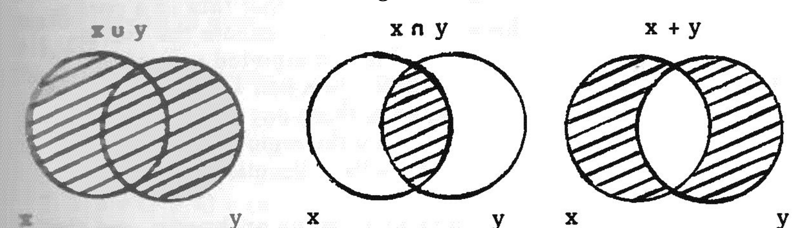
THE ALGEBRA OF LOGIC

By ARTHUR H. COPELAND, SR.

In arithmetic the operation + can be used to combine a number x with a number y to form the number $x + y$. Similarly for the operation x. In an anologous manner the word *or* can be used to combine a sentence *x or y*. Similarly for the word *and.* The development of this anology results in boolean algebra (named after George Bool). We symbolize the words *or* and *and* respectively by $\cup$ and $\cap$ and symbolize the sentences x or y and x and y respectively by $x \cup y$ and $x \cap y$. In legal documents one ofter encounters expressions of the form *x and / or y* meaning ***x or y or both,*** and this is precisely the meaning of the symbol $x \cup y$. On the other hand we symbolize the sentence *x or* y ***but not both*** by $x + y$. Presently we shall state the properties of the symbols $+, \cap$ in a set of postulates (or axioms) and shall see that these symbols bear close analogies to the operations +, x of arithmetic.

Let us picture x and y as regions in the plane. Then $x \cup y$ is pictured as the region consisting of the points which belong to *x or y or both*, [illegible] is the region consisting of the points which belong to *x and y*, and $x + y$ is the region consisting of the points which belong to *x or* y ***but not both.*** See figure 1.

Figure 1



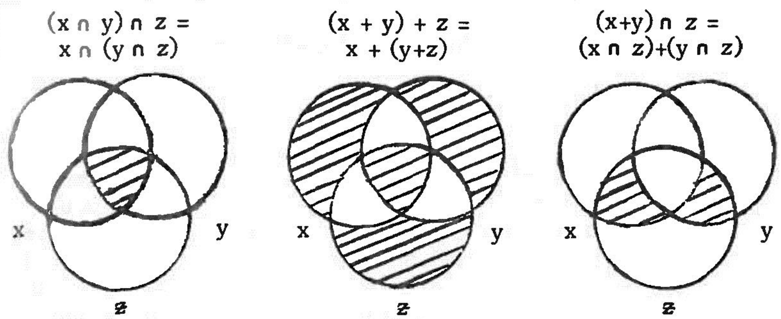
These are called Venn Diagrams. The regions $x \cup y$, $x \cup y$, $x + y$ are called respectively the union, intersection and symmetric difference of x and y. Clearly $x \cup y = y \cup x$, $x \cap y = y \cap x$, $x + y = y + x$.

Consider next a third region z. It can readily be seen from figure 2 that $(x \cap y) \cap z = x \cap (y \cap z)$, $(x + y) + z = x + (y + z)$, $(x + y) \cap z = (x \cap z) + (y \cap z)$.

---

[1] James E. Case Memorial Lecture, St. Louis University, April 25, 1957. This paper was presented before the Missouri Gamma, St. Louis University at their initiation, when Dr. Copeland was the guest speaker for the occasion.

Figure 2



Note that if we replace the symbol $\cap$ by the symbol $\times$ then the equations which appear in figure 2 become laws of arithmetic.

Suppose that there is a large region u (for example, u might consist of the entire plane) such that u contains all of the regions we are considering. Then for any region x (under consideration) we have $x \cap u = x$. Thus u is analogous to the number 1 of arithmetic and we shall use the symbol 1 to denote such a region. The region $1 + x$ does not contain any point of the region $x \cap 1 = x$ but does contain every point of the region 1 which does not lie in x. We call the region $1 + x$ the complement of the region x with respect to the region 1. In the case of sentences, $1 + x$ is interpreted as the sentence ***not x***. Note that $x \cup (1 + x) = 1$ is the sentence *x* or ***not x*** and that this sentence is always **true.** Thus 1 denotes the universally true sentence and is called the tautology. Note also that $x \cap (1 + x)$ is the sentence ***x and not x***, that this is a contradiction and hence false for every x. We let 0 denote the universally false sentence. If x and $1 + x$ are interpreted as regions then since there are no points common to x and $1 + x$, we must interpret $x \cap (1 + x) = 0$ as the region without any points. Thus 0 is called the empty set or null set. Since the region $x + 0$ is the same as the region x we have $x + 0 = x$ as in arithmetic. Also note that $x \cap 0 = 0$.

We now consider some differences between arithmetic, and the system we are developing. Since the region $x \cap x$ consists of all points common to *x* and x, it follows that $x \cap x = x$ for every *x*. In arithmetic we define the reciprocal of x (if $x \neq 0$) as the number y which satisfies the equation $x \times y = 1$. In the present system there is no region y such that $x \cap y = 1$ except when $x = 1$. Also in arithmetic we define the negative of x by the equation $x + (-x) = 0$. In the present system we have $0 = x \cap (1 + x) = (x \cap 1) + (x \cap x) = x + x$; and we can interpret the equation $x + x = 0$ as stating that every x is its own negative. This latter property enables us to transpose a term in an equation without changing the sign. Thus if $x + y = z$ then $x + y + y = z + y$. But $x + y + y = x$ and hence $x = z + y$.

We let B denote the set of all sentences with which we are concerned in a given investigation, or the set of all regions with which we are concerned. We list the properties of B, +, $\cap$, 0, 1 in the following set of postulates. The preceeding discussion was introduced to make the postulates seem natural but henceforth all needed properties can be derived from the postulates.

- **P 1.** $x + y$ is in B if x and y are in B
- **P2.** $x + y = y + x$
- **P3.** $(x + y) + z = x + (y + z)$
- **P4.** $x + 0 = x$
- **P 5.** $x + x = 0$
- **P 6.** $x \cap y$ is in B if x and y are in B
- **P7.** $x \cap y = y \cap x$
- **P8.** $(x \cap y) \cap z = x \cap (y \cap z)$
- **P 9.** $x \cap 1 = x$
- **P 10.** $x \cap x = x$
- **P 11.** $x \cap (y + z) = (x \cap y) + (x \cap z)$.

The system satisfying these postulates is called a ***boolean ring with a unit.*** If P 9 is omitted the system is called simply a ***boolean ring.*** The postulates make no mention of the symbol u. However this symbol can be defined in terms of + and $\cap$ as follows.

D 1. $x \cup y = x + y + (x \cap y)$.

It can readily be seen that this definition agrees with the interpretation given to $x \cup y$. The symbol $\sim x$ is also used to denote the sentence ***not x*** (or the complement of the region x). Thus

D 2. $\sim x = 1 + x$.

The corresponding system based on the symbols $\cup$, $\cap$, $\sim$ is called a ***boolean algebra.*** All of the properties of a boolean algebra are consequences of postulates P1 to P11 together with definitions D 1, D2.

The following theorems give some of these properties.

- **T 1.** $x \cup y = y \cup x$ is in B if x and y are in B
- **T 2.** $(x \cup y) \cup z = x \cup (y \cup z)$
- **T 3.** $x \cap \sim x = 0$, $x \cup \sim x = 1$
- **T 4.** $x \cap (y \cup z) = (x \cap y) \cup (x \cap z)$, $x \cup (y \cap z) = (x \cup y) \cap (x \cup z)$
- **T 5.** $\sim(x \cup y) = (\sim x) \cap (\sim y)$, $\sim(x \cap y) = (\sim x) \cup (\sim y)$
- **T 6.** $x \cup 0 = x = x \cup x$, $x \cup 1 = 1$, $x \cap 0 = 0$
- **T 7.** $x + y = (x \cap \sim y) \cup (y \cap \sim x) = (x \cup y) \cap \sim(x \cap y)$.

A very simple but nevertheless useful boolean algebra is one in which B contains only 0 and 1. The properties are given by the following tables.

Table 1: $x + y$

x \ y	0	1
0	0	1
1	1	0

Table 2: $x \cap y$

x \ y	0	1
0	0	0
1	0	1

This boolean algebra is used in switching circuits, $x = 1$ means that a certain switch is closed and $x = 0$ means that the switch is open. If two switches are in parallel, the situation is represented by $x \cup y = x + y + (x \cap y)$ and if two switches are in series the situation is represented by $x \cap y$. A somewhat more general boolean algebra is used in the design of electronic digital computers. This can be described as follows. Let

$$x = (x_1, x_2, \dots x_n), \quad y = (y_1, y_2, \dots y_n)$$
$$0 = (0, 0, \dots 0), \quad 1 = (1, 1, \dots 1)$$
$$x + y = (x_1 + y_1, x_2 + y_2, \dots x_n + y_n)$$
$$x \cap y = (x_1 \cap y_1, x_2 \cap y_2, \dots x_n \cap y_n)$$

where each x_k is 1 or 0 and each y_k is 1 or 0. Thus the elements of this boolean algebra are sequences of 1's and 0's. Such a sequence can be interpreted as the sequence of digits of a number written in the scale of 2. Electronic devices can be constructed to perform the boolean operations on these sequences. In turn the arithmetic operations are defined in terms of the boolean operations together with the operation of shifting the decimal point (or more properly, the radix point since the scale is 2 instead of 10). The reader can verify that above two examples satisfy postulates P 1 to P 11.

Recall that a boolean ring is defined in terms of two operations $+, \cap$ whereas a boolean algebra requires three operations $\cap, \cup, \sim$. It is possible to state all of the properties of a boolean algebra (or boolean ring) in terms of a single operation called Sheffer's stroke operation and defined as follows.

D 3. $x|y = (\sim x) \cup (\sim y) = 1 + (x \cap y)$

Thus if one can construct an electronic device capable of performing the stroke operation then he can construct a device capable of doing problems in boolean algebra. This claim is substantiated by the following readily proved theorem.

T 8. $x \cap y = (x|y)|(x|y)$, $x \cup y = (x|x)|(y|y)$, $x|x = \sim x = 1 + x$, $x|(x|x) = 1$, $1|1 = 0$.

In probability one uses a boolean algebra which contains the word if in addition to the words ***and, or, not.*** We denote the word ***if*** by the symbol / and denote the sentence ***y if x*** by y/x. We also interpret the sentence y/x as ***y on the hypothesis that x has been verified.*** The properties which the operation / is required to possess are given in postulates 12 to 18. When x is the universally false sentence (i.e., when $x = 0$) then x cannot be verified and it does not make sense to form the sentence ***y on the hypothesis that x has been verified.*** Otherwise y/x is regarded as a bona fide sentence and hence an element of the boolean algebra B (see P 12). Note the analogy to arithmetic in which division is defined except when the denominator is 0. Henceforth when we write a symbol such as y/x it will be understood that x, y are in B and $x \neq 0$.

Postulates 13 through 16 are readily seen to agree with the interpretation of the symbol / given above. In order to understand P 17 consider the case in which x is the sentence ***a die will be thrown,*** y the sentence ***the die will turn up an odd number*** and z the sentence ***the die will turn up a 3.*** Then $z/(x \cap y)$ is interpreted as the sentence ***the die will turn up a 3 if it is thrown and turns up an odd number.*** The sentence $(z/x)/(y/x)$ is interpreted as ***the die will turn up a 3 when it is thrown if it turns up an odd number when it is thrown.*** These two sentences are regarded as having the same meaning and hence $z/(x \cap y) = (z/x)/(y/x)$.

Suppose that we have given two sentences x, z where $x \neq 0$. It is often convenient to interpret z as a sentence of the form y/x and we shall assume that this is always possible (see P 18). It turns out that y is not uniquely determined by x and z but that $x \cap y$ is unique. Hence (if $x \neq 0$) we are always able to combine the sentence x with the sentence y/x to form $x \cap y$. The operation which produces this combination is denoted by x. Thus
$x \cap y = x \times (y/x) = x \times z.$

It is also convenient to assign a meaning to the cross product $x \times z$ even when $x = 0$ and in this case the product is defined to be 0. Thus D 4. The cross product $x \times y$ is such that

a) if $x \neq 0$ then $x \times y = u \cap x$ where $u/x = y$

b) if $x = 0$ then $x \times y = 0$.

The above discussion should not be regarded as constituting proofs of the postulates 12 to 18 but as suggesting which properties of the operation / are advisable to demand in order that this operation will be useful in developing the theory of probability. We have the following postulates.

P 12. y/x is in B if x, y are in B and $x \neq 0$.

P 13. $x/x = 1$.

P 14. $(y \cap z)/x = (y/x) \cap (z/x)$.

P 15. $(\sim y)/x = \sim(y/x)$.

P 16. If $y/x = 0$ then $y \cap x = 0$.

P 17. $z/(x \cap y) = (z/x)/(y/x)$.

P 18. Given x, y where $x \neq 0$ there exists z such that $z/x = y$.

The following theorem is a simple consequence of the postulates together with D 3.

T 9. $(x \times y)/x = y$ and $x \times (y/x) = y \cap x$.

We can also interpret the sentence y/x (i.e., ***y if x***) as ***y is implied by x*** or ***x implies y.*** However this implication does not signify that there is necessarily a logical relationship between ***x*** and ***y.*** In fact probabilities are assigned to the sentences in B and in particular a probability less than 1 might well be assigned to the sentence ***x implies y,*** i.e., to y/x. On the other hand if ***y*** is a logical consequence of ***x*** then $y/x = 1$. The type of implication defined by the equation $y/x = 1$ is closely related to but not identical with the strict implication of C. I. Lewis.

We consider again a boolean algebra which is required to satisfy only postulates 1 to 11. It is convenient to use the following notation.

$$\bigcap_{t=1}^{n} x_t = x_1 \cap x_2 \ldots x_n, \quad \bigcup_{t=1}^{n} x_t = x_1 \cup x_2 \ldots x_n.$$

If the x's (where t = 1, 2, ... n) are interpreted as regions then $\bigcap_{t=1}^{n} x_t$ consists of those points which belong to *all* of the regions x_t and $\bigcup_{t=1}^{n} x_t$ consists of those points which belong to some (i.e., at least one) of the regions x_t. If the x_t's are sentences then we interpret $\bigcap_{t=1}^{n} x_t$ as the sentence *for all t,* x_t and we interpret $\bigcup_{t=1}^{n} x_t$ as *for some t,* x_t or as *there exists a t such that* x_t. It is also customary to use the symbols $\bigcap_{t} x_t$, $\bigcup_{t} x_t$ in which the range of *t* is not specified. In this case, *t* may range over a finite set of integers, over all positive integers, over all real numbers or over an arbitrary set.

Let the elements of B be interpreted as regions and consider a fixed point of the region 1. Let $\mathfrak{f}$ denote the set of all regions of B which contain this point. Then $\mathfrak{f}$ has the following properties.

a) If x, y are in $\mathfrak{f}$ then $x \cap y$ is in $\mathfrak{f}$.
b) If x is in $\mathfrak{f}$ and y is in B then $x \cap y$ is in $\mathfrak{f}$.
c) 0 is not in $\mathfrak{f}$.
d) If x is in B then either x is in $\mathfrak{f}$ or $\sim x$ is in $\mathfrak{f}$.

a set $\mathfrak{f}$ of elements of B having properties a), b) c), d) is called a maximal filter. If d) is omitted the set is called simply a filter. Note that a region x is contained in $\mathfrak{f}$ if and only if x contains the point with respect to which $\mathfrak{f}$ is defined.

We can now interpret the elements of an arbitrary boolean algebra B as regions in some space. The maximal filters of B are interpreted as the points of the space. The filters which contain an element x of B are interpreted as the points which the region x contains. The Stone representation theorem states that such an interpretation is always possible. We omit the proof of this theorem.

Next let x be a region of B and $\mathfrak{f}$ be a point of the region 1. Let

$$\varphi(x, \mathfrak{f}) = \begin{cases} 1 \text{ if } \mathfrak{f} \text{ is in } x \\ 0 \text{ if } \mathfrak{f} \text{ is not in } x. \end{cases}$$

If x is fixed then φ is a function of $\mathfrak{f}$ and the set of points for which $\varphi(x, \mathfrak{f}) = 1$ is the set of points of the region x. If $\mathfrak{f}$ is fixed then φ is a function of x and the set of elements x for which $\varphi(x, \mathfrak{f}) = 1$ is the filter associated with the point $\mathfrak{f}$. Again for fixed $\mathfrak{f}$ the function φ converts every element of B into either 1 or 0 and hence transforms B into the simple boolean algebra containing only the elements 1, 0. If we interpret 1 as truth and 0 as falsity then φ can be interpreted as assigning either truth or falsity to every sentence in B. Tables 1 and 2 are then described as truth tables for the operations +, n.

Consider an expression y formed by combining the elements x_1, x_2, ... x_n, 0, 1 by means of the operations +, n. In order to decide whether or not a point $\mathfrak{f}$ belongs to the region y it is sufficient to know for each k (k = 1, 2, ... n) whether or not $\mathfrak{f}$ belongs to x_k. That is, the value of $\varphi(y, \mathfrak{f})$ is uniquely determined by the values of $\varphi(x_1, \mathfrak{f})$, ..., $\varphi(x_n, \mathfrak{f})$. In other words, the truth or falsity of y is uniquely determined by the truth or falsity of x_1, ... x_n. Suppose that we have two expressions y, z formed from the elements x_1, ... x_n, 0, 1 and that z is true when y is true and z is false when y is false for all possible assignments of truth or falsity to x_1, ... x_n. Then $\varphi(y, \mathfrak{f}) = \varphi(z, \mathfrak{f})$ from all points $\mathfrak{f}$ and hence y and z are the same regions, i.e., y = z. This device can be used to prove formulas in boolean algebra.

To illustrate let us prove T 8. We first obtain truth tables for x|y and xn y. From D3 and tables 1 and 2 it readily follows that x|y is false when x and y are both true but true otherwise. Similarly xu y is false when x and y are both false but true otherwise. Hence one can readily check that the formula xu y = (x|x) | (y|y) holds when x = y = 0 and when x = 0, y = 1 and when x = 1, y = 0 and when x = y = 1. Therefore the formula is universally valid. The remaining formulas of T8 can be similarly proved. All of the formulas which do not involve the operation / can be checked by this method and the reader will find it instructive to perform such checks. It can be proved that the operation / cannot be defined in terms of +, n and that the above method is not applicable to formulas involving this operation.

We shall present one further interpretation. In the theory of probability it is customary to let 1 denote success and 0 denote failure. An experiment assigns to a sentence x either a success (i.e., a verification) of a failure (i.e., a non-verification). Since the function? assigns to x either the value 1 or 0 we interpret the the probability of x as the probility that φ will assign to x the value 1, i.e., the probability that the function φ will take on the value 1.

University of Michigan.

BOOK REVIEWS

Mathmatical Analysis. By Tom M. Apostol. Addison-Wesley Mathematics Series. Reading, Mass., 1957. xii + 553 pp., $8.50

This book is designed "to fill the gap between elementary calculus and advanced courses in analysis" and to introduce "the reader to some of the abstract thinking that pervades modem mathematics." Guided by these aims and the desire to go as deeply as possible, the author has written an admirable book. It is perhaps appropriate to describe this text as a modern *Cours d' Analyse*. It certainly ranks with Courant's *Differential and Integral Calculus* and Franklin's *Treatise on Advanced Calculus* and it is this reviewer's opinion that it will be found to be rather more suitable as a text for advanced undergraduate students of mathematics than these books.

This book is elementary in the sense that it deals with "Advanced Calculus" rather than "Real Variables." However, the high standard of rigor and the extensive treatment will require a degree of sophistication not universal among students of courses titled "Advanced Calculus." Therefore it is students who have had a semester or two of that course that will benefit most from this text. (This book would be an ideal companion for a shipwrecked senior student of mathematics.) The exposition is complete but rather brief and only a limited number of examples are given, but the good indices and a wealth of exercises (about 500 in number) will partly make up for the brevity of style.

It is not possible to list here all of the many interesting topics discussed or adequately to suggest the richness of the selection. We will be content with a mere outline. Chapter 1 gives an informal introduction of the real numbers as a complete ordered field and the complex numbers as ordered pairs of reals. Certain facts from algebra and calculus are presupposed. Chapter 2 introduces the elements of set theory and defines relations and functions. The next chapter is a nice discussion of point-set topology in n-dimensional Euclidean space with proofs of the Bolzano-Weierstrass and Heine-Borel theorems. The next two chapters deal with limits and continuity and with derivatives, including Taylor's theorem. Chapters 6 and 7 are rather complete treatments of partial differentiation with applications to Jacobians, the implicit function theorem, extrema and Lagrange multipliers. Next, functions of bounded variation and rectifiable curves are discussed An absorbing development of the Riemann-Stieltjes integral (in the general form due to S. Pollard) is given in Chapter 9, including the fundamental theorem of calculus, interchange of the order of differentiation and integration, necessary and sufficient conditions for Riemann-integrability in terms of content and Lebesgue measure, and contour integrals of complex functions. The next chapter treats multiple integrals, change of variables, and Green's theorem. Chapter 11 discusses vectors, vector fields, differential geometry of curves, surface area, and Stokes' and Gauss' theorems. Following are two chapters dealing with infinite series and infinite products of complex numbers and sequences of functions; both go more deeply than is usual. A chapter on improper Riemann-Stieltjes integration prepares for an elegant development of Fourier series which treats questions of convergence, localization, and summability and gives an introduction to the Fourier and Laplace transforms. Finally. Chapter 16 is a brief but lucid account of complex variable including the Cauchy integral theorems, Laurent expansion, and the calculus of residues.

When one bears in mind that complete proofs are given (except in Chapter 1), it is truly surprising that Professor Apostol has been able to include so much material in this very fine text This has largely been

done by preparing the ground very carefully and by good arrangement. The content is fascinating, the proofs are concise but not cryptic, the notation is well-chosen, the style is readable, the exercises are plentiful, and the format is attractive. Who could ask for more?

University of Illinois Robert G. Bartle

Introduction to Operations Research. By C. West Churchman, Russell L. Ackoff, and E. Leonard Arnoff. John Wiley & Sons, Inc., New York, 1957. x + 645 pp., $12.00.

This book presents an introduction to the fast developing field of Operations Research. It gives a survey of the field and illustrates each topic by an example which incorporates a basic technique.

For the benefit of those who are not acquainted with O. R., it is the application of the "scientific method" to operations which involve such elements as men, machines, weather, and organizations. An interesting example is given in Chapter 15: "Traffic Delays at Toll Booths". It recounts how O. R. was used to determine the optimum number of toll booths for the Lincoln Tunnel. Naturally, more booths would be open at rush hour than late at night, but from there on the optimum number was an educated guess. As elements of this problem there are vehicles (fairly reliable), drivers (sometimes rational), rush hours, slack periods, weather, operating budgets, toll collectors available, etc. "The question is how to select. . . (the number of toll booths) . . . in a logical manner with a minimum of arbitrariness." O. R. was successful because it provided a cogent framework for an apparently overwhelming amount of data, and thereby made possible a logical choice.

The book is written for the "prospective consumer" and "prospective practitioner" of O. R. For the student who is a prospective practitioner it provides an excellent description of the nature of the work and the extent to which mathematics can be employed The level of mathematical proficiency assumed for the reader is variable. On p. 345 the $\sum$-notation and the notion of inequalities are explained, while on p. 385 knowledge of differential equations is assumed Perhaps a more insistent demand for mathematical maturity arises from the steady use of mathematical symbols and from the necessity to abstract. Facility in abstraction is rare indeed among people who have not studied mathematics. This book will also be useful in courses in O. R. Since there are no problem sections, it is not a text book in the ordinary sense of the word

In the first part of the book the authors describe rather general O. R. methods. They discuss data and its organization by means of a model (theory or abstraction). They describe how a problem is solved in terms of the model which has been formulated The balance of the book is devoted to applications of O. R. which illustrate certain techniques for finding models and the actual mathematics used in their solution. The mathematics here is within the grasp of a good undergraduate student. The applications, being in the fields of industry and the social sciences, may well appeal to those who enjoy mathematics, but are not drawn to engineering. The only major omission • and it is major indeed • in the discussion of applications of O. R. is the military. Undoubtedly this is due to security classification.

The subject matter is well presented in a sequence of ten units: Introduction, The Problem, The Model, Inventory Models, Waiting Time Models, Replacement Models, Competitive Models; Testing, Control and Implementation; and Administration of Operations Research. Each unit contains a few chapters discussing aspects of its topic. Each chapter has a very readable discussion of the problem, techniques of solution, and summary. There is an excellent bibliography at the end of each chapter. The authors have taken particular care to state the assumptions that they have made in the solution of each problem. Very often they leave it to the astute student to deduce the limitations thus imposed on the solution. The authors make frequent mention of the use of high speed computing machines in the solution of O. R. problems. They do not stress the large amount of time which it takes to formulate a problem in machine language, or the large amount of training that a practitioner must have in order to know WHEN to use a machine for solution

Within the university this book certainly belongs on the browsing shelf of every technical library, and will be very useful in O. R. courses on both the advanced undergraduate and graduate levels.

Urbana, Illinois Jane Ingersoll Robertson

Introduction to Riemann Surfaces. By George Springer. Addison-Wesley Press, Reading, Mass., 1957. viii + 307 pp., $9.50

There has been so much recent interest in complex analytic manifolds that the expected half-life of any organized account of the subject is a matter of a few months at most. Higher dimensional complex analytic manifolds are rooted in a beautiful and classical theory, however, the study of Riemann surfaces, and it is indeed surprising that there are so few good expositions of the latter subject. A good text-book on Riemann surfaces is consequently a welcome addition to the literature.

The present book opens with a detailed discussion of a few elementary Riemann surfaces and some physical motivation, and it closes with an exposition of the Riemann-Roch theorem and other classical results for the compact case. Since an enormous amount of material occurs in the intervening pages, a blow-by-blow account of a few of the highlights in in order.

The introduction provides a rough image of some of the theorems which occur later in the book, and since a wave of the hand loses some of its power when translated into print, the author has preferred to concentrate on a few examples which illustrate as many points as possible. Thus the Riemann surfaces of some algebraic functions, in particular, elliptic functions, are constructed explicitly by beautifully illustrated scissors-and-glue techniques, and complex potential theory is introduced in the suggestive language of fluid mechanics which guided Riemann himself.

Chapter 2 returns to the ground floor to provide the basic topology necessary for the definition of an abstract Riemann surface, which invokes Weyl's definition of a manifold. "This chapter is clear and concise, and it is followed by two equally clear and concise chapters on the definition of the Riemann surface of a complete analytic function and on the coverings of two-dimensional manifolds.

The fifth chapter is much longer, which is not surprising since it contains a fairly complete introduction to the algebraic topology of two-dimensional manifolds, specializing to the orientable case just in time to avoid giving a complete classification. Some of the exposition is necessarily hurried here, and it demands some prior knowledge of abelian groups. However, it is difficult to imagine a cleaner development of polyhedral and singular homology theory, and the reader can easily acquire the necessary group theory elsewhere.

Chapter 6 contains the minimum basic vocabulary of exterior differential calculus, tactfully avoiding an honest definition of a differential. It seems to the reviewer that the omission is unfortunate and that the development could easily have been clarified merely by introducing differential forms as alternating forms in the appropriate number of variables on the tangent

space. Stokes' theorem is proved by means of a specific partition of the identity, the Hodge operator is presented in terms of a fixed coordinate system, and several elementary results on harmonic and analytic differentials follow. Incidentally, a proof of appropriate special cases of the theorems of Hodge and de Rham is sketched (in that order!) in the exercises for Chapters 6 and 7. These results deserve a better fate in a text on Riemann surfaces, even at the expense of a few extra pages. The same remark applies to the existence and construction of Green's function, which makes its only appearance in an exercise at the end of chapter 8.

Chapters 7 and 8 deal with the method of orthogonal projection and the classical existence theorems for harmonic differentials, and Chapter 9 treats the classification of simply connected Riemann surfaces, triangulation, and Schwarz' classification of the surfaces which admit continuous conformal deformations.

As announded earlier, the book closes with a burst of fireworks over a compact Riemann surface, including discussions of the Riemann-Roch theorem, abelian differentials, and algebraic function fields, capped by a few hints on open surfaces. The quest for elliptic integrals, begun with such vigor in the introduction, closes the book.

There are a few problems at the end of each chapter, designed largely to illustrate the techniques of the corresponding chapter or to lead to classical results which are not given in the text, as noted in Chapters 6, 7, and 8. The reviewer would have preferred more problems, coupled with more references to current literature or suggestions for meaningful generalizations to higher dimensional complex manifolds. For some reason, even the excellent centennial collection of papers, "Contributions to the Theory of Riemann Surfaces", by Ahlfors, et al., is not listed in the bibliography.

The preceding complaints are rather picayune compared to what the author has actually accomplished. The book presents an enormous amount of material in a very clear fashion, and it should make an excellent text-book for an advanced course in complex variables, presented at the beginning graduate level. "Introduction to Riemann Surfaces" is an especially welcome addition to the literature, and it is likely to remain a standard reference and text for many years.

University of Illinois Howard Osbom

Statistical Analysis of Stationary Time Series. By Ulf Grenander and Murray Rosenblatt. John Wiley and Sons, New York, 1957. 300 pp. $11.00

This is a study of a probabilistic model, the stationary stochastic process, yielding a mathematical idealization of such varied physical phenomena as ocean waves, random noise, and turbulence, and perhaps of certain biological and social phenomena. The authors concentrate chiefly on the statistical problem: Assuming that one has been realistic in his choice of a general model for a given empirical situation, how can one best estimate the unknowns of the model? They warn against restricting the model too severely in the beginning and criticize some of the earlier studies on this basis. Accordingly, much of the book is devoted to a non-parametric model for which the problem is one of estimating the spectral distribution function. Several techniques for doing this are analyzed. For example, a method for obtaining a confidence band for the spectral distribution function is discussed. Some of this material, part of which is original with the authors, is published in a book for the first time.

The authors assume that the reader has a knowledge of statistics and probability theory equivalent to that contained in *Mathematical Methods of Statistics*, by H. Cramér. About 50 problems are given at the end of the book. These add considerably to its usefulness.

This book should be of great interest not only to statisticians and probabilists interested in the mathematical theory developed but also to electrical engineers, physicists, and the like, who will here find that their needs have been kept in mind. It is also recommended to anyone who wishes to see a brilliant example of the fruitful interplay of mathematics with its areas of application.

University of Illinois D. L. Burkholder

Symposium on Monte Carlo Methods. H. A. Meyer, Editor. New York, John Wiley & Sons, 1956. xvi + 382 pp. $7.50

The Monte Carlo method is a technique of numerical analysis which has proved useful in many mathematical problems. For example, it has been demonstrated that the following general problems can be handled by Monte Carlo techniques: inverting matrices and determining their eigenvalues and eigenvectors. solving certain differential and difference equations, and evaluating multiple integrals.

Since the Monte Carlo approach is relatively new and not usually introduced at the undergraduate level, it may be helpful to point our that solving a mathematical problem in this way requires two separate steps: a random variable must be found which has the property that some or all of its parameters are the solution of the problem; then, these parameters must be estimated by sampling techniques.

The volume under review consists primarily of 18 papers given at a symposium on Monte Carlo methods conducted by the Statistical Laboratory of the University of Florida under the sponsorship of the Wright Air Development Center of the Air Research and Development Command, in March, 1954.

The papers may be grouped into four sections:

(1) An introductory note by A. W. Marshall which briefly traces the development of Monte Carlo methods since the last symposium on the subject in 1949. An attempt is also made to integrate the newer results published in this volume with the older and now standard techniques of Monte Carlo. This section will be very useful to those who are not already familiar with the Monte Carlo method.

(2) Four papers on the generation of random numbers and more general random variables by Butler, Lytle, Metropolis, and the team of Taussky and Todd.

(3) Eight papers on the theoretical aspects of the Monte Carlo method by Albert, Curtiss, Kahn, Marshall, Motskin, the team of Trotter and Tukey, and Walsh (two papers).

(4) Four papers on specific applications of Monte Carlo methods by the teams of Arnold, Bucher, Trotter, and Tukey; Beach and Theus; and individual contributions by Berger, and Dismuke.

Also included are abstracts of papers by Ulam and Vickery, and a brief note on the teaching of Monte Carlo methods by Walther.

Finally, the volume includes an 87 page bibliography divided into three parts: theory and applications of Monte Carlo methods; the generation and testing of random digits, and known sources of random digit tables; and articles and books which discuss problems whose solutions require sampling techniques.

All in all, the volume will serve as an excellent reference for persons working in numerical analysis. However, the beginner will find the material difficult and quite discontinuous. For the novice, this reviewer suggests starting with a few articles of an expository nature, such as those by D. P. Mc Cracken, N. Metropolis, and S. Ulam, which are re-

ferred to in the bibliography. A good introduction to Monte Carlo methods which has appeared since this symposium publication is "Monte Carlo Methods", by George W. Brown, Chapter 12 in *Modem Mathematics for the Engineer,* edited by Edwin F. Beckenbach, New York, McGraw Hill, 1956.

University of Pittsburgh and Carnegie Institute of Technology Kenneth S. Kretschmer

BOOKS RECEIVED FOR REVIEW

W. G. Cochran and G. M. Cox: Experimental Designs, New York, John Wiley, 1957, $10.75

R. E. Johnson and F. L. Kiokemeister, *Calculus with Analytic Geometry,* Boston, Allyn and Bacon, 1957, $7.95

R. D. Luce and H. Raiffa: Games and Decisions, New Yolk, John Wiley, 1957, $8.75

D. C. Murdoch, *Linear Algebra for Undergraduates,* New Yolk, John Wiley, 1957, $5.50

W. Feller, *An Introduction to Probability Theory and its Applications, Volume 1,* New Yolk, John Wiley, 1957, $10.75

H. A. Simon: Models of Man, New Yolk, John Wiley, 1957, $5.00

NOTE: All correspondence regarding books and reviews should be addressed to FRANZ E. HOHN, 374 MATHEMATICS BUILDING. UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS.

THE NATIONAL MEETINGS AT PENN STATE

A national meeting of the Pi Mu Epsilon Fraternity was held at Pennsylvania State University August **26 – 27, 1957,** in conjunction with meetings of the American Mathematical Society, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics. The first event was a dinner meeting of the National Council, devoted primarily to a discussion of proposed changes in the Constitution and other matters to be brought before the fraternity.

The regular meeting, attended by **45** members and **3** guests, convened at **7** p.m. to hear papers by two student members, as follows:

"Envelopes of Certain Families of Conics", Miss Katherine **Lipps,—** Missouri Gamma

"Mathematics in Turkish High Schools", Mr. Ali Tangoren—Louisiana Alpha

The papers were followed by a business meeting, at which certain changes in the constitution were discussed which will subsequently be brought before the chapters for a vote. Representatives of **22** of the **64** chapters of the fraternity were present. The first petition for an affiliate chapter - at Evendale, Ohio - has been approved, and also a petition for a chapter at Douglass College. Because of increased expenses for the Pi Mu Epsilon Journal, for transportation, and for other items, the initiation fee is being raised to **$2** per member as a result of a mail vote taken prior to the meeting.

A second session for papers was held Tuesday afternoon at **3:30.** The attendance included five members not present Monday, and the program was as follows:

"**Symmetry** Groups and Molecular Structure", Director-General J. Sutherland Frame—Michigan Alpha

"On The Convergence of Fourier Series", Mr. Tom K. Boehme—Oklahoma Alpha

"The Perpetual Calendar", Mr. Francis J. Felix—Pennsylvania Delta.

Chapters were represented at the meeting as follows (an asterisk denoting an official delegate): Alabama Alpha: *J. P. Beaulien, H. S. Thurston; Alabama Beta: *W. H. Fulcher; D. C. Alpha: G. H. Butcher; Florida Beta: T. L. Wade; Georgia Alpha: R. M. Rutledge; Illinois Alpha: **M.** C. Hartley, A. Seybold; Iowa Alpha: *H. P. Thielman; Kansas Gamma: C. B. Read; Kentucky Alpha: R. H. Sprague; Louisiana Alpha: H. Cohen, *A. I. Tangaren; Michigan Alpha: *J. S. Frame; Missouri Alpha: *M. Cummings; Missouri Gamma: F. **Regan,** *K. S. Lipps; Nebraska Alpha: **C. C.** Camp; New Jersey Alpha: A. Sullivan, *J. Taub; New York Alpha: **N.** Cole; New York Beta: *A. Anderson, **L.** Grinstein; New York Gamma: H. Griffin; New York Eta: H. F. Montague, **M.** Montgomery, *H. B. Warner; Ohio Epsilon: F. Brooks, T. E. Bush; Oklahoma Alpha: R. V. Andree; Oklahoma Beta: T. **K.** Boehme; Oregon Alpha: D. R. Davis, R. L. San **Soucie;** Pennsylvania Beta: *J. Beedleman; Pennsylvania Gamma: G. E. **Raynor;** Pennsylvania Delta: R. **G. Ayong,** F. Felix, O. Frink, R. T. **Heimer,** F. Kocher, M. L. Oliver, F. **W.** Owens, H. B. Owens, G. N. Raney, M. Silander, **W.** A. **Sillars;** Wisconsin Alpha: J. Kelley; Wisconsin Beta: **R.** L. San Soucie, R. D. Wagner.

Guests were O. L. Bayksin, E. **Colabi,** V. G. Davis, M. P. Emerson, Joel Patek.

Michigan State University — J. S. Frame, Director General

OPERATIONS

Science needs you

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This section of the Journal is devoted to encouraging advanced study in mathematics and the sciences. Never has the need for advanced study been as essential as today.

Your election as members of Pi Mu Epsilon Fraternity is an indication of scientific potential. Can you pursue advanced study in your field of specialization?

To point out the need of advanced study, the self-satisfaction of scientific achievement, the rewards for advanced preparation, the assistance available for qualified students, etc. it is planned to publish editorials, four in each issue, prepared by our country's leading scientific institutions, to show their interest in advanced study and in you.

We are fortunate to have in this issue editorials from Monsanto Chemical Company, McDonnell Aircraft Corporation, Emerson Electric, and the Explosive Division of Olin Mathieson Corporation.

We are indeed grateful to these institutions for their editorials and their material support of this publication.

In future issues it is planned to show a cross section of America's scientific industries through their editorials encouraging advanced study.

The future holds a scientific career for those who have the fortitude to seek it. Don't "hitch your wagon to a star", make yourself the STAR.

McDONNELL AIRCRAFT CORPORATION

ADVANCED TECHNICAL TRAINING IN THE AIRCRAFT INDUSTRY


L. I. Mirowitz

By L. I. MIROWITZ
Supervisor of Structural Dynamics,
Engineering Division

The aircraft being produced and designed today are a far cry from those flown prior to and during World War II and even as recently as three to five years ago. Guided missiles which were in their infancy during World War II are now important factors in our defense system. The complexity of the design, the achievement of higher speeds, automatic flight control, more powerful propulsion, and greater operating efficiency, coupled with the requirement of limited space and minimum weight, have made the aircraft and missile an intricate flying machine. Associated with the increase in the complexity of the design, a new breed of engineer has evolved supplementing the efforts of the designer in achieving a successful flight article. These engineers are not only trained in the traditional fields of engineering, but, in addition, are schooled in the concepts of advanced sciences and their attendant mathematical techniques. In general, they do not use a drawing board as their engineering tool. They sit behind a desk and analyze and predict the special characteristics of aircraft performance and behavior with which they are concerned. This type of individual combines the training of a scientist with that of an engineer and for lack of a better name let us call him a **"sciengeer".** At McDonnell Aircraft Corporation the ratio of "sciengeers" and other technically trained personnel with respect to the traditional designers working on a particular aircraft or missile project of latest design is approximately 2 to 1.

The "sciengeer" is an engineer with interests and training in the more theoretical sciences and research developments. Since mathematics is the language of science, he has relatively high training and extended exposure to mathematical techniques. He is found usually in engineering departments such as Aerodynamics, Controls, Thermodynamics, Dynamics and Structures. The work in these departments is generally on a high technical level and a thorough knowledge of mathematics is not only desirable but absolutely essential. The mathematical techniques which are most commonly utilized in the function of these departments are theory of differential equations, matrix algebra, vector analysis, theory of probability, operational techniques, and programming and utilization of high speed automatic computers, both of digital and analog type.

As more sophisticated aircraft and missile systems are being designed, the need for the "sciengeer" will ever increase. At the same time our colleges and universities must be able to fill this need with qualified personnel. This will require a reorientation of approach and effort in the training process of our future engineers at all training levels. It has become apparent that the traditional hand-book techniques of engineering are not adequate anymore if we are to pierce daringly the unknown. Past experience can serve as a useful guide but cannot dictate and overshadow those approaches which result from imaginative thinking based on good, sound scientific judgement.

Our goal is to recapture and maintain the scientific leadership in the world. The **"sciengeers"** of today and tomorrow will be the spearhead in the drive toward this goal.

Explosive Division, **OLIN *MATHIESON* CORPORATION**

A BLUE SKY FOR INDUSTRIAL MATHEMATICIANS

By
DR. JAMES BARR,
DR. HAROLD R. WEISBROD,
DR. P. S. McKETTRICK,
of the Research and Development Section,
Solid Propellant Organization

Looking back upon the magnificent industrial growth of our nation, one should pause and consider what this growth means in terms of opportunities for technical specialists. Consider this from the vantage point of an industrial scientist, trained in the discipline of the scientific method, trained for work chosen on the basis of personal interest but, fortuitously, also in the interests of his employer. We look to industry for opportunities. Industry looks to us for our special abilities, which can be channeled into the creation of products that possess or can create a market. The ability to create is a direct function, in most cases, of the extent of academic preparation. Realizing this, one must develop a deep appreciation for the advantages of higher learning, especially in the field of our special interests.

You have a right to know what you are being trained for, and you ask, "what are mathematicians doing in industry today?" To attempt to answer this question for all industry would, indeed, be naive. Instead, let me say something about the area I know best, the explosives industry.

Years ago, only a sampling of mathematicians could find a niche in the explosives field. Explosives were in the chemists domain. A few mathematicians were needed to compute gun ballistics, and others were engaged in related thermodynamic and thermochemical problems. Trajectory calculations and analysis of projectile flight offered intriguing problems. Much of this work was reduced to an exact science by mathematical rigor.

Industries have been forced by competition to keep abreast of the state of the art advances in production and technical know-how. The pressure to obtain and hold a fair share of the potential market has forced each company to find better ways of making superior products. The old way of advancing by hit-or-miss, cut-and-try techniques is no longer sufficiently fast or economical. Managers have been forced to go to scientific methods of design and production to gain and hold a fair share of business. Engineers, of course, were generally in good demand, but then as products became even more complex, increasing numbers of other scientists – chemists, physicists and mathematicians – were added to industrial payrolls.

Today, the explosives industry in seeking new markets for its products and skills has entered, among other things, the guided missile field. Here it has found vast outlets for the talents of research-minded scientists of almost every category. Mathematicians are spotted throughout the industry in increasing numbers. With the advent of giant electronic computers the efficiency of each mathematician has been multiplied.

To cite an example of the use of the computers, consider one problem recently programmed successfully in Olin Mathieson. It was necessary to know a critical ballistic parameter, specific impulse, of candidate high-performance solid rocket propellants. Specific impulse is a measure of the thrust at combustion pressure a unit mass of pmpellant will give when burned in a unit time interval. It has primary bearing on missile velocity, range, size and payload. In a rocket propellant, it is obviously desirable to obtain the highest possible specific impulse compatible with the other physical and chemical properties of the propellant.

To illustrate a specific demand upon the propellant mathematician, I will show how specific impulse would be calculated. Now, the equation for specific impulse looks very simple:

$$I_{sp} = 0.932\sqrt{c_p(T_c-T_e)}$$

where I_{sp} equals specific impulse expressed in seconds, or, more correctly, pounds-force developed per pound-mass burned per second; c_p equals heat capacity of the exhaust gases (calories per 100 grams per Kelvin degree); T_c equals Kelvin temperature of the chamber gases; and T_e equals the Kelvin temperature of the exhaust gases. The constant term is a correction factor for conversion of units. The difficulty attendant with the solution of this equation arises from the requirement that the products of combustion must be known before c_p and T_e can be determined, but the stoicheometry in turn depends on temperature of the product mixture.

Essentially, what must be done is to assume a particular temperature and then determine whether it is the correct one. Since the temperature range involved may be as great as 4000°K, there is a lot of room in which to make assumptions, and one could have a most tedious time of it. Accordingly, one of two approaches must be taken if time is critical:

(1) Make a few simplifying assumptions or guesses by which time may be saved at the expense of accuracy.

(2) Assign the task, especially if this is to become a frequently recurring task, to an electronic computer.

First, let me give you some idea of how a simplified calculation could be made. If a propellant formulation is definitely known, in terms of the per cent composition of its chemicals, it is not too involved a task to calculate for each chemical element present the number of gram-atoms per 100 gram of propellant. But to determine the gaseous products one would have to know the equilibrium constants for all reactions involving these elements of the composition which may occur to any significant extent.

Here is where the difficulty arises. These equilibrium constants, obviously, are functions of temperature. Moreover, there are a great many reactions encountered at these high temperatures which would not be encountered significantly at lower temperatures, or even known. For example:

$$H_2 \longrightarrow 2H$$
$$M_2O_3 \longrightarrow M_2O_2 + O$$
$$Cl_2 \longrightarrow 2Cl$$
$$H_2O \longrightarrow H + OH \longrightarrow 2H + O$$

There are, therefore, a great many reactions involved. Moreover, even the problem of obtaining accurate data for the thermochemical properties of these unusual species is formidable.

The simplest way out is to set up some rule for estimating gaseous product distribution. The simpler the rule, the more uncertain but quicker the result. In practice one may be working with a propellant containing largely the elements carbon, hydrogen, oxygen, and nitrogen, with perhaps some halogen and some metals. The selection rule might dictate:

(1) Assume the metals become metal oxides of the common valence state (i.e., $2Al \longrightarrow Al_2O_3$).
(2) Assume the nitrogen becomes gaseous and diatomic ($2N \longrightarrow N_2$).
(3) Assume the halogen becomes the hydrogen halide (i.e., $X + H \longrightarrow HX$).
(4) The remaining oxygen is apportioned between the carbon and hydrogen by some order of preference, according to the reactions: $C + O \longrightarrow CO$, $CO + O \longrightarrow CO_2$ and $2H + O \longrightarrow H_2O$.
(5) Any remaining hydrogen goes to hydrogen gas ($2H \longrightarrow H_2$).

Thus, using such an arbitrary rule, a hypothetical gas mixture could be calculated which could be used for further calculations. (Note: In recent papers, such as the July, 1956 issue of Jet *Propulsion*, short-cut methods have been worked out for some systems on the assumption that, in step (4) above, the mole ratio of water to carbon dioxide was two to one).

In this five-step method, the equilibrium constant difficulty may be avoided, but at the cost of serious uncertainty in the results. In order to introduce equilibrium constants, it is necessary to introduce simultaneous equations. One of the reactions involved is the well-known water-gas reaction:

$$CO + H_2O \rightleftharpoons CO_2 + H_2$$

It is apparent that use of the water-gas reaction is, from the point of view of accuracy, a definite improvement over the arbitrary assumptions of steps (4) and (5) above. But, consider the problems involved. Suppose the symbols (C), (H), and (O), respectively, represent the gram atoms of carbon, hydrogen, and oxygen (left over from that used in steps 1 and 3). Then, letting the chemical formula represent the number of moles:

$$CO + CO_2 = (C)$$
$$2H_2 + 2H_2O = (H)$$
$$H_2O + CO + 2CO_2 = (O)$$

$$K = \frac{CO_2 \cdot H_2}{CO \cdot H_2O}$$

where K is the equilibrium constant of the water-gas reaction. To solve this set of equations, K must be known, which means the temperature must also be known since K is a function of temperature. But, as it happens, the temperature cannot be known until the products have been revealed. The reason for this is that the overall chemical reaction will liberate heat (to be transformed into mechanical energy), and the amount of heat depends on the stoichiometry of the products. The temperature is calculated from (a) the heat liberated from the reaction, and (b) the heat capacity of the products. But as the temperature rises, equilibrium shifts take place, so the stoichiometry of the products changes. Hence, again the vicious circle.

One could, of course, go through the process of choosing a series of temperatures, substituting the corresponding values of K, calculating CO, CO_2, H_2, and H_2O, then calculating the heat liberated and, from the heat capacities of the various products, calculate the heat absorbed by the products in attaining the chosen temperatures. Then, by extrapolation, some idea can be gained of the desired temperature, T_c, at which all the heat liberated by the reaction would be absorbed by the products.

This is technically feasible, though tedious. in the case I have described. There are many more reactions actually occurring, however, and to attempt to solve a much more elaborate set of simultaneous equations involving many equilibrium constants, all temperature dependent, would be extremely time consuming when done on a desk calculator.

The value of the electronic computer now becomes apparent. Such a machine actually can perform the requisite series of iterated calculations over and over again, until it arrives by elimination at the temperature at which the heat output and heat absorption balance each other. The programming of such an operation would consist of setting up the complex interrelations of product gas concentrations in the form of simultaneous equations involving equilibrium constants (as functions of temperature) and the propellant composition. Fundamental thermochemical data are needed (heat capacities, latent heats, heats of formation).

The steps might be described as follows:
(1) Determine the gram-atoms of each element available.
(2) Determine the equilibrium constants at a given temperature.
(3) Solve the simultaneous equations for product gases.
(4) Calculate the heat of reaction based on the calculated stoichiometry.
(5) Calculate, from heat capacities and latent heats, the heat absorption for this temperature.
(6) Compare 4 and 5.

One of the great values of the electronic computer is its ability to compare two numbers and then decide, on the basis of this comparison, what its next step would be to repeat the operation, using a slightly different temperature, until the heat balance was obtained.

The second great value of the machine is that the iteration process can be set up to go on and on, automatically, as long as is necessary to obtain the proper comparison of results. Thus, the machine can keep trying temperatures all day long without going out of its mind or taking a coffee break; actually, it generally operates so rapidly in a case such as this that it usually requires only a few minutes.

There is a bit more to the calculation than this. The term T_e in the specific impulse equation is related to the calculated temperature T_c adiabatic law:

$$T_e/T_c = (P_e/P_c)^{\frac{nR}{c_p}}$$

where p is pressure, n is the total number of moles of gas, and R is the gas constant. Even calculation of this relationship requires knowledge of the stoichiometry of the products.

Even with computers there are limits of accuracy due to (1) idealized assumptions such as the adiabatic law (2) limitations on the validity of input thermochemical data, especially at the high temperatures involved. The computer may also be of use here in handling such data in that it can, if necessary, curve-fit the equilibrium constant or heat capacity data into the temperature function form required.

Incidentally, even the short-cut methods have unexpected difficulties. Suppose one had arbitrarily estimated the product stoichiometry. Then the heat of reaction, OH, could be calculated, but to determine the temperature, T_c, I would face the problem of solving the following equation:

$$-\Delta H = \int_{T_o}^{T_c} c_p dt$$

for T_c (where T_o is the initial temperature). Since C_p is generally given in terms of a series,

$$c_p = a + bT + cT^2 + \ldots$$

the resulting integrated equation would probably be a cubic equation. So even the short-cut methods involve operations which would be rather complicated and time-consuming if done by hand.

As one brief example, then, propellant specific impulse and its calculation have become important to our industry. On the individual's level, its adaptation to computer techniques has eased the mathematician's burden in eliminating the otherwise tedious work of hand iteration. In its place has been substituted a technical problem having much of the intrigue of chess.

In recent months expansion of the missile industry appears to be keeping up with the expansion of the cosmic universe. Here, at last, we are witnessing not the time-worn dream but the real thing, the saga of man's penetration into outer space. This is the generation which has seen the rocket nearly vanish as a feature of festive display, be reborn as a thundering giant capable of vaulting precious cargos through the vicious tentacles of earth's air and gravity to bridge wide chasms in time and space. Soon, mathematicians will no longer optimize trajectories only, for trajectories will blend into orbits and orbits again into trajectories. Clearly, the science of astronautics will not be developed in a day. There is much work to be done. Your part in it requires, but will surely follow, your adquate academic preparation to meet the mounting challenge.

MONSANTO CHEMICAL COMPANY

APPLIED MATHEMATICS IN THE CHEMICAL INDUSTRY

Dr. Cooper

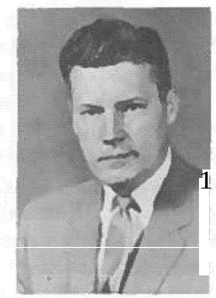
By

DR. LEON COOPER,
Manager,
Applied Mathematics Section,

and

DR. JOEL O. HOUGEN,
Systems Section,

Research and Engineering
Division



Dr. Hougen

The normal path to successful operation of chemical processing plants has generally been through laborious and time-consuming laboratory pilot plant development and trial and error procedures and designs based on fragmentary empirical data. This situation exists because of the vast complexity of the phenomena occurring. In chemical processing apparatus, typical concurrent phenomena might include chemical reactions together with both heat and mass transfer by various mechanisms and fluid flow. These situations prevail indistillation and absorption apparatus and chemical reactors, for example.

Until effective computational aids were developed, the possibility rarely existed of arriving at a solution to the mathematical equations which might be developed for the purpose of describing the given situation. By utilizing electronic computers, solutions can now be obtained in a finite time; and as a result, a sharp increase in need for more comprehensive problem formulation and the application of fundamental theories to chemical processing has emerged.

The recognition of this need is indicated by the transformation which so-called fundamental courses in chemical engineering are undergoing. Thirty years ago chemical engineering was little more than a training in industrial chemistry in which a large number of facts on current practice were disseminated. Then a few observing individuals noted that certain basic phenomena were common in many processes, and thus courses in "unit operations" developed. Evidence indicates that this era is approaching an end, and one notes that courses are being offered which stress fundamentals and first principles upon which the unit operations depend. In many instances, this implies use of principles long ago explored by physicists; in others, new areas are being explored. Along with the application of fundamental physical and chemical notions has developed the need for formulation of associated mathematical models, the derivation and solution of mathematical equations, and the association of significant parameters with properties of real systems.

Concurrent with this trend to make chemical engineering "more scientific," an increase in the demand for experts in related fields will be certain to occur. In particular, mathematical specialists will be required to assist in applications of theory.

Chemical engineers in particular face formidable problems in the application of fundamental principles, largely because of the many media involved in a typical chemical process. It is not uncommon to be concerned with electrical, mechanical, hydraulic, pneumatic, thermal, and chemical phenomena in a single process. Chemical engineers must, therefore, have an exceptionally wide acquaintance with various disciplines and must be able to move from one to the other and to interrelate them easily.

The rapidly accelerating pace in the exploitation of mathematical processes in the chemical industry has placed the average chemical engineer (especially the older ones) in an awkward position. While they may be aware that the scientific content of their technology can and is being increased, they frequently do not have time nor perhaps can be expected to become conversant with mathematical details. To solve this dilemma, they must turn more and more to mathematicians and physicists to bail them out.

Managements and practicing engineers recognize an increasing need for mathematicians to assist in the formulation of the problems and especially in effecting solutions and interpreting information. With the facilities to compute and obtain answers, many avenues of endeavor in which the mathematician is specially suited have been opened. Their contributions can now be measured more conveniently by the economic yardstick. In direct proportion their "market value" will increase.

A number of areas of mathematics which are currently being explored by engineers and scientists in the chemical industry are listed below:

1. Solution of ordinary and partial differential equations (linear and non-linear), especially by numerical methods.
2. Numerical analysis: Solution of sets of equations, polynomial approximations, interpolation techniques, et cetera.
3. Statistical analysis: Regression analysis (linear and non-linear), analysis of variance, design of experiments, autocorrelation techniques.
4. Matrix methods and eigenvalue problems.
5. Operations Research: Linear programming, probability theory, et cetera.

In all these, individuals highly skilled in mathematics can render invaluable assistance and can find areas of challenging, profitable, and fruitful work.

EMERSON ELECTRIC MFG. CO.

THE NEED FOR SCIENTIFIC STUDIES IN THE SCHOOLS AND INDUSTRY

By WING LEONG, Chief,
Stress Analysis Division,
Electronics and Arionic Division,
Missiles & Structures Laboratory

Wing Leong

In the transition from the campus to industry, the young engineer, often, discovers to his own amazement, the complexity of the task in industry which lies before him. There is a feeling of inadequacy to cope with the theoretical problems. In my particular field of stress analysis, this feeling is more pronounced because of the intangibles involved.

Thus motivated by the technical challenges of the profession, the young engineer seeks post-graduate studies which will enable him to solve more complex problems as well as enhance his creative abilities. Here at Emerson Electric, management feels so strongly about the necessity of advanced studies, that it encourages its young engineers and scientists to pursue technical studies at the graduate level. The company assists financially in any technical program of study at the local universities which leads to self improvement, and is directly related to the employe's work.

In many instances, an advanced degree may be earned. In the pursuance of a doctorate's degree, in the engineer's field of specialization, the company reimburses the employee upon attainment of the degree. In addition to the acquisition of knowledge, the engineer is rewarded with advancements, both in position and in salary after demonstrating increased technical competence as result of his studies. As a result of this policy, every engineer in the Stress Analysis Division is either attending, or has completed, at least one advanced course in mathematics, applied mechanics, or engineering.

It might be noted here that this philosophy not only benefits the individual and industry, but the welfare of the nation. With the latest achievements by the Russians in the successful launching of Sputnik's I and II, it is quite evident that greater and greater competence in scientific work must be achieved if we are to maintain a strong position in the world. President Eisenhower in his speech on Science and National Security on November 7 stated, "According to my scientific friends, one of our greatest and most glaring deficiencies is the failure of us in this country to give high enough priority to scientific education and to the place of science in our national life."

But aside from the military considerations, a strong scientific and engineering manpower potential will also advance our already high standard of living. For with the age of automation and the atom, many more devices are being conceived to make the convenience of modern living even more exciting.

Two decades ago, aircrafts were propeller driven, rocketry was in its infancy and the automobiles had manual gear shifts; television was still in its experimental stages.

Today it's the jet and atomic age, jet aircrafts are in military service with the inauguration of commercial service only months away. Thermo-nuclear devices, rockets, and missiles, are weapons in the stockpile for military defense. In the automotive field, higher performances are being designed into automobile engines besides the introduction of innumerable new devices to ease the effort of motoring, Atomic energy is being harnessed for the generation of electric power. This certainly represents a tremendous step forward from two decades ago. Yet, this was possible only through scientific research and engineering advances which is directly dependent upon the training of engineers and scientists. Since many of the devices are infinitely more complex than its predecessors in the present technological era, the requirements for personnel, trained technically at the graduate and post-graduate levels becomes more acute.

The world of tomorrow which we might appropriately name the Satellite age is upon us. It is expected that scientific advances will occur mote rapidly than in the past. Therefore, the need for highly trained scientists and engineers in the future will become more critical.

To assure our well-being and security in the future, everyone of us in the field of engineering and science must make every effort to encourage our young engineers and scientists to pursue advanced studies in the scientific field. We must encourage our students in the high schools to study mathematics and sciences and prepare themselves for careers in science and engineering. The rewards for scientific proficiency and accomplishments must be emphasized.

Presented here are a few pertinent statistics associated with the theme of this paper: Mr. J. M. MacBrayer wiriting in The Journal of Industrial Engineering July-August 1957, "Engineering - America's Most Critical Resources" states "In 1950, eight college students came across the graduation platform to accept diplomas before one engineer came. By next June the number will be fifteen."

"Only about 16% of high school graduates entering college each year enroll in engineering courses. Unfortunately, more than one half of these young hopefuls flunk out along the way or switch to other courses. Most deans of engineering schools explain that this problem is based on poor high school preparation in science and mathematics."

Col. Edward H. Wynn, USAF, speaking before the Institute of the Aeronautical Sciences in January, 1957 on "The Challenge to America's Leadership in Technology" quoted figures supplied by the National Science Foundation on 30 July 1956 that Soviet Russia graduated 59,000 engineers as compared to 22,600 in the United States, for the year 1955. He further states that during the next ten years, the U.S. will have produced 425,000 engineers and 500,000 scientists under continued favorable encouragement of organized effort against 670,000 engineers and 435,000 scientists in Soviet Russia.

In conclusion, it is evident that positive efforts must be made to emphasize the need for scientific studies, in the high schools, universities, and the post-graduate institutions of higher learning. Students, entering high school, should be told of the vast opportunities in the fields of engineering and science. Those who possess the aptitude, should be encouraged and carefully guided to follow a selective curriculum which will prepare the student for engineering and scientific pursuits in the universities. Means must be found to increase the number scholarship grants to worthy students. A program must be formulated to attract top mathematics and science teaching talent to the secondary schools. Certainly the students will be no better than the quality of the instruction.

Thus with the proper quantity and quality of students enrolled in engineering schools, provided with the incentives for a scientific profession, and instructed by a competent faculty, the number of engineering graduates required for the future of our country will be assured.

NEWS AND NOTICES

Edited by Mary L. Cummings, University of Missouri

We solicit material for ***News and Notices,*** a new department which is to be a feature of the Pi Mu Epsilon Journal. We hope to have personal news items about members from all the chapters, and urge members and friends of the fraternity to keep us informed. Also, we suggest that the local corresponding secretaries take responsibility for submitting news of members and ex-members of their chapters. Items of interest would include the winning of honors – prizes, scholarships, and fellowships – the beginning of graduate studies, the earning of advanced degrees, and the presentation of papers. In fact, we want news of Pi Mu Epsilon members who are doing interesting and outstanding work, or who have noteworthy accomplishments or distinctions.

(Please name the individual, his chapter and university, and his class year.
Sample: John Doe, Kansas Alpha, University of Kansas '56, has received a Fulbright scholarship for study in The Netherlands and is now spending a year at the University of Leyden. Or: Jane Doe, Missouri Alpha, University of Missouri '56, is working for the Ph. D. degree at the University of Chicago.)

Current release

Lt. (j.g.) Robert **E.** Downing, U.S.N., New York Alpha, '52 was killed **May** 14, 1957 in a jet plane crash at San **Diego, Cal.**

Two members of Pi Mu Epsilon, Edward B. Roessler of Davis, California and Louis A. **Pardue** of Blacksburg, Virginia are District Governors of Rotary International for the 1957-58 fiscal year. Dr. **Roessler** is Professor of Mathematics at the University of California and is Statistician at the Agricultural Experiment Station in Davis, cal. Dr. **Pardue** is **Vice-President and Direc**tor of Graduate Studies of **V.P.I,** in Blacksburg, **Virginia.**

The Rotary International Awards Fellowships went to 130 graduate students throughout the world for 1957-58. These fellowships are awarded without regard to race, creed or citizenship. For information concerning these fellowships write Rotary International, 1600 Ridge Ave., Evanston, Illinois.

News should be sent to Mary L. Cummings, Mathematics Department, University of Missouri, Columbia, Missouri,

DEPARTMENT DEVOTED TO CHAPTER ACTIVITIES

Edited by

Houston T. Karnes, Louisiana State University

EDITORS NOTE: According to Article **VI,** Section 3 of the Constitution: "**The** Secretary shall keep account of all meetings and transactions of the chapter and, before the close of the academic year, shall send to the Secretary General and to the Director General, an annual report of the chapter activities including programs, results of elections, **etc."** The Secretary General now suggests that an additional copy of the annual report of each chapter be sent to the editor of this department of the ***Pi Mu Epsilon Journal.*** Besides the information listed above, we are especially interested in learning what the chapters are doing by way of competitive examinations, medals, prizes and scholarships, news and notices concerning members, active and alumni. Please send reports to Chapter Activities Editor **Houston** T. **Karnes,** Department of Mathematics, Louisiana State University, Baton Rouge 3, Louisiana. These reports will be published in the chronological order in which they are **received.**

REPORTS OF THE CHAPTERS

ALPHA OF NEW YORK, Syracuse University

In a**ddition to a tour** of the campus computing center **the New** York Alpha Chapter had two program meetings during **1956-57. *The following* papers** were **presented:**

"Operations Analysis"

"The Simple Di**fference Equation"**

Officers for 195**7-58 are: President, John Ryff; Vice-Presi**dent, **Glendon** Bibbins; Secretary* Mary **Doscher;** Treasurer, Samuel **Patton.**

EPSILON OF OHIO, Kent State University

The Ohio Epsilon Chapter held two program meetings during 195657. The following papers were **presented:**

"A Use of the Calculus of Variations in the Design **of** a Guided Missile" by Professor John W. Kaiser

"**Putnum** Test Examinations" by Professor Byron B. **Dressler.**

In addition the members of the chapter attended the lectures given by Dr. Albert W. Tucker of Princeton University which were co-sponsored by the Mathematical Association of America and Kent State **University.** The lecture subjects of Dr. Tucker **were:**

"**New** Patterns in Mathematical Education'*

"**Theory** of Games – Problems of Competition and **Cooperation"**

"Topological Index"

The chapter had several social functions during the year. At the initiation meeting seven new members were inducted. As a chapter project for **1957-58** the members agreed to be available for tutoring undergraduates in mathematics. The fees were set at **$2.00** per hour for individuals and **$1.50 per hour for groups consisting of no** more than five persons per group.

Miss Lucv Sanchez was **selected as the** delegate to the national **meet**ing of Pi Mu **Epsilon.**

Officers for 1957-58 **are: Director,** Dr. Foster L. Brooks; President* Earl **Hopkins;** Secretary* Lucy **Sanchez;** Treasurer, **Marilyn Boich;** Corresponding Secretary, Dr. Frances **Harshbarger.**

ALPHA OF WISCONSIN, Marquette University

The Wisconsin Alpha Chapter held seven meetings during the 1956-57 year. Thirteen new members were inducted.

At the annual banquet, this year held in conjunction with Sigma Pi Sigma, the honorary physics fraternity, the winners of the annual Frumveller examination were announce&

First: Robert Ochsner
Second: Gus Strassburger

Speakers and topics for the year were:

"Godel's Theorem" by John Barton
"Boolean Sigma Algebra and Integration Theory" by Dr. Lester Heider, SJ
"Time Formulas" by George Sell
"The Theory of the Mathematical Basis of the Arts" by Laurence Deysach
"Some Mathematical Theories in Psychology" by William Golomski
"The Maxwell Distribution" by John Barton
"Epistomology and the Sciences" by Dr. Edgar Simmons

Officers for 1957-58 are: President, John Barton; Vice-President, George Sell; Treasurer, Romain Jankowiak; Recording Secretary* Benjamin Zanin; Corresponding Secretary, Donald Powichroski.

ALPHA OF MONTANA, Montana State University

The Montana Alpha Chapter started the 1956-57 year with the annual awarding of the Pi Mu Epsilon prizes to Brooke Billings, Fredrick Eisenbeis, and Donald Lee Smith. These prizes are given to the three freshmen who place highest on an entrance examination in mathematics.

The following papers were presented at meetings during the year:

"Dimension Theory"* by Dr. Joseph Hashisaki
"How to Calculate Logarithms" by Dr. Louis Schmittroth
"How to Count on your Fingers" by Director James Rowland
"Algebra of Switches" by Dr. Wayne Cowell
"Transcendental Numbers" by Dr. William Myers

Eight new members were inducted at the initiation meeting.

Officers for 1957-58 are: Director* Donald Sward; Vice-Director, Andrew Browman; Secretary-Treasurer, Gavin Bjork.

ALPHA OF KANSAS, University of Kansas

The Kansas Alpha Chapter, during 1956-57, did not have many meetings listed as Pi Mu Epsilon, however, there were other activities wherein the members took part. The Undergraduate Seminar met weekly to hear papers by undergraduates. The Mathematics Club met once each month. In addition, the department sponsored the "Colloquia" where research papers were presented.

The following papers were presented at Pi Mu Epsilon Meetings:

"Mathematical Millenium" by the Reverend William C. Doyle, S.J. of Rockhurst College
"A Modem Theorem of Ancient Geometry" by Sharon Steele.

Twenty-three new members were initiated during the year.

DELTA OF ILLINOIS, Southern Illinois University

The Illinois Delta Chapter of Pi Mu Epsilon was installed January 18, 1957 at Southern Illinois University, Carbondale, Illinois. Dr. S. S. Cairns, Director General, presided and was the guest speaker at the initiation banquet.

Three regular meetings were held during the remaining part of the year; two of these were initiations at which time a total of twenty-six members were inducted. The following papers were presented:

"Peculiarities of Polyhedra" by Dr. S. S. Cairns
"Generating Functions" by Dr. Fred Brafman
"Cryptography in an Algebraic Alphabet" by Ross Schneider.

Awards presented at the spring banquet were the outstanding award received by Inis Richardson, and the problems contest awards won by Ross Schneider, first place, and Lawrence Larson, second place.

Officers for 1956-57 were: President, Ross Schneider; Secretary, Shirley Gipson; Treasurer, Abd Daqqaq; Faculty Advisor, Morton Kenner.

ALPHA OF OKLAHOMA, University of Oklahoma

The Oklahoma Alpha Chapter held seven program meetings during the year 1956-57. The following papers were presented:

"Is Mathematics Consistent?" by Dr. John Giever
"Convex Bodies" by Dr. T. K. Pan
"The Stability of Digital Computers" by Mr. John Thomas
"The Monte Carlo Method" by Mr. James Bradford
"Pursuit Curves"* by Dr. Arthur Bemhart
"Boolean Mathematics" by Mr. Tom Head
"Egyption and Babylonian Mathematics" by Miss Betty Ruth Estes.

The annual spring banquet honoring thirty-five new members was held on May 17th. Dr. Laurence Snyder, Dean of the Graduate College, University of Oklahoma, spoke on "A Semester in Hawaii."

The chapter sponsored a problem-box contest, and the award was given to the winners at the spring banquet.

Officers for 1957-58 are: Director, Robert Stong; Vice-Director, Bill Hodges; Secretary-Treasurer, DeWayne Carter; Faculty Sponsor, Earl LaFon; Corresponding Secretary, Dr. Dora McFarland.

BETA OF WISCONSIN, university of Wisconsin

During the year 1956-57 the Wisconsin Beta Chapter held ten meetings. These included business sessions, program meetings and social gatherings. Two initiations were held at which a total of forty-three new members were inducted Dr. R. D. Wagner spoke at the first initiation on the history of the local organization and the work of the national. The second initiation was in conjunction with the annual spring banquet. The speaker was Professor H. P. Pettit of hlarquette University.

The annual Freshman Award was won by Curtis Wagner

The following papers were presented during the year:

"A General Survey of Numerical Calculations" by Robert Evey
"The Theory of Retracts" by E. R. Fade11
"Topology of the Plane" by C. E. Burgess
"The Theory of Knots" by J. B. Kruskal

Officers for 1956-57 were: Director, Daniel Robinson; Vice-Director, Homer Bechtell; Secretary-Treasurer, Barbara Perske; Faculty Advisor, R. H. Bing.

Officers for 1957-58 are: Director, Hiram Paley; Vice-Director, Jim Kister; Secretary-Treasurer, Carol McDuffee; Faculty Advisor, Joseph B. Kruskal.

ALPHA OF FLORIDA, University of Miami

The Florida Alpha Chapter held five meetings during 1956-57. At the initiation meeting eight new members were inducted into membership.

The following papers were presented during the year:

"Stress Analysis" by Dr. Emmet Low
"Knots" by Dr. R. A. Roberts
"Jordan Algebras" by Dr. A. A. Albert of the University of Chicago
"Ham Sandwich Theory" by Dr. M. K. Fort, Jr. of the University of Georgia.

Officers for 1957-58 are: Director, Dr. Emmet Low; Vice-Director and Treasurer, Homer Lowe; Secretary, Beverly Brechner.

ALPHA OF NORTH CAROLINA, Duke University

The North Carolina Alpha Chapter held two meetings during 1956-57. The following papers were presented:

"Computing for Oil" by Dr. T. M. Gallie
"Stochastic Processes in Genetics" by Dr. F. G. Dressel

A total of thirty-nine new members were initiated at two different meetings.

Officers for 1957-58 are: Director, David Lewis Nealy; Vice-Director, Robert Oscar Gamble; Secretary, Carol Annette Cleave; Treasurer, Constance M. Malmar.

BETA OF FLORIDA, Florida State University

The Florida Beta Chapter was installed with appropriate ceremonies and a banquet on October 5, 1956. Installing officer was the (then) Vice-Director General, Professor J. Sutherland Frame of Michigan State University. Twenty members were initiated at that time, and seven others, initiated elsewhere, were recognized as members of the new chapter. Professor Frame spoke at the banquet on the "History and Traditions of Pi Mu Epsilon". Earlier in the day, he gave two specialized talks on "Symmetry Groups" and on "Power Series Expansions for Inverse Functions".

A second initiation banquet was held on May 20, 1957, at which time fourteen additional members were initiated The speaker was Associate Dean J. Paul Reynolds of the Florida State University College of Arts and Sciences, who spoke on "New Programs within the University Affecting Mathematics".

The following papers were presented at program meetings:

"Analogue Computers" by John G. Harvey, II
"Number Theory" by Dr. Clifton N. Mills
"Mathematical Recreations" by a group of students
"Mathematical Needs and Services at a Computing Center" by Mr. Grady Cox and Mr. R. D. Lawson of Vitro Corporation, Eglin Air Force Base, Florida
"New Ideas in the Teaching of High School Mathematics" by Dr. Eugene Nichols, Mr. Robert Fouch, and Mr. Robert Kalin of the FSU University School
"Non-Euclidean Geometry" by John T. MacLean
"Perfect Numbers" by Professor Paul McCarthy

Officers for 1956-57 were: Director, Professor Charles W. McArthur; Permanent Secretary, Professor James W. Ellis; President, John G. Harvey, II; Vice-president, John T. MacLean; Secretary-Treasurer, Carl A. Schulz, Jr.

Officers for 1957-58 are: President, Bobby L. Sanders; Vice-president, Albert L. Leduc, Jr.; Secretary-Treasurer, Miss Ted T. Thomas.

ALPHA OF MISSOURI, University of Missouri

The Missouri Alpha Chapter held its annual initiation banquet on May 2, 1957. Professor Sabri Sami of the Department of Civil Engineering was the speaker. Professor Sami is a native of Egypt. The annual prizes in the calculus were awarded as follows:

First Prize ($25.00) — David Lee
Second Prize ($15.00) — Charles R. Morton
Third Prize ($10.00) — Thomas Kilker

Officers for 1957-58 are: Director, John Cartwright; Vice-Director, Donald Barnett; Secretary, Irvin Klauss; Treasurer, John Sutterby.

GAMMA OF MISSOURI, St. Louis University

The Missouri Gamma Chapter held four meetings during the 1956-57 year in addition to the amual banquet. The following papers were presented:

"An Example of a Connected Periodic Metric" by Dr. John Riner.
"Some Theorems on the Fregier Point and Its Generalizations" by Dr. Francis J. Regan.
"S(x) and C(x)" by Dr. John J. Andrews.
"The Algebra of Logic" by Dr. Arthur H. Copeland, Sr., University of Michigan.

Seventy-nine new members were initiated by the chapter.

Mr. Kevin O'Sullivan won the Junior award of ten dollars, Mr. Richard Andres won the Senior award of fifteen dollars. Sister Gregory Marie hleyer, O.S.F. received the annual James W. Garneau award of twenty-five dollars for being the highest ranking senior majoring in mathematics.

Officers for 1956-57 were as follows: Director, Joseph Moser; Vice-Director, Daniel Troy; Secretary, Sister Mary Kenneth Kolmer, Ad. P.P.S.; Faculty Advisor and Permanent Secretary-Treasurer* Dr. Franas Regan.

ALPHA OF NEBRASKA, University of Nebraska

The Nebraska Alpha Chapter held eight program meetings and two initiation banquets during 1956-57. A total of thirty-seven new members were initiated The following papers were presented at the program meetings:

"Counting With Large Numbers" by Donald Miller
"Elementary Game Theory" by Charles R. E. Wright
"How to Find Your Way out of a Maze" by Melvin Thomton
"Very High Energy Accelerators" by Prof. E. J. Zimmerman
"Projective Geometry" by Dr. Earl J. Schweppe
"Geometrical Fallacies" by Ralph Mortimore
"A Discussion of the Putnam Mathematical Competition" by Dr. Earl J. Schweppe
"Organization of Mathematical Studies in Europe" by Prof. Hugo Ribeiro.

The following awards were made:

Freshman Mathematical Award - William Gingles
Freshman Algebra Award — Harry Tolly
Annual Prize Examinations: I (tie) David Cassel
(tie) Troy Fuchser
II (1st) Marvin Kessler
(2nd) Keith Schrader

Officers for 1957-58 are: Director, Robert Gallawa; Vice-Director, Ralph Mortimore; Treasurer, Ronald Homby; Secretary, Sharon Hocker; Faculty Advisor, Dr. Donald W. Miller.

GAMMA OF ILLINOIS, DePaul University

The Illinois Gamma Chapter held seven meetings during the 1956-57 year including the official installation of the new chapter on October 17, 1956. Professor S. S. Caims officiated at the installation and initiated the fifteen charter members of the new chapter. Eight new members were initiated during the year.

The following papers were presented at the program meetings

"Mathematics at DePaul" by Dr. G. L. Weiss
"Boolean Algebra in Switching Circuits" by Mr. P. Krajkiewicz
"Elementary Topology" by R. Frankowski
"Introduction to Set Theory" by J. Lenguadoro
"Introduction to Group Theory" by R. Mertes
"Systems of Curves in the Plane" by Dr. J. DeCicco
"The Concept of a Group" by M. Issa

Officers for 1956-57 were: Director, Professor Louis M. Weiner; Permanent Secretary, Professor Guido L. Weiss; President, Paul Drajkiewicz; Secretary, Joseph Lenguadoro; Treasurer, Ralph Frankowski.

Officers for 1957-58 are: President, Charles Mitchell; Vice-President, Anthony Behof; Secretary and Treasurer, Louis Aquilla.

ALPHA OF GEORGIA, University of Georgia

The Georgia Alpha Chapter held eight program meetings during 1956-57. In addition there were three initiation meetings including the annual banquet A total of twenty-two new members were initiated. The following papers were presented:

"The Banach-Tarski Paradox" by Dr. M. L. Curtis
"Boolean Algebra and Switching Circuits" by Dr. John J. Jewett
"Jet Engine Parameters" by John V. Hancock
"The Envelope of the Simpson Lines of a Triangle" by Dr. D. F. Barrow

"Numerical Analysis" by R. A. Willoughby
Fundamental Group" by James T. Finely, Jr.
"Non-Euclidean Geometry" by Dean Boswell
"Paradoxes" by Dr. M. K. Fort.

For the second straight year Fred B. Rose was the winner of the Chapter's Prize Award for excellence in mathematics beyond the first year in college. Marvin Atha wrote the best paper on the freshman mathematic examination.

Officers for 1956-57 were: President, James T. Hinely, Jr.; Vice-President, Ronald M. Rutledge; Secretary, Helen C. Raisty; Treasurer, Joel J. Knight.

Officers for 1957-58 are: President, C. Wayne Patty; Vice-President, Fred B. Rose; Secretary, Ernie Anglin; Treasurer, Ronald M. Rutledge; Faculty Advisor, John J. Jewett.

ALPHA OF OREGON, University of Oregon

The Oregon Alpha Chapter held three business meetings and four program meetings during the 1956-57 year. The following papers were presented:

"A College Mathematics from a Physicist's Viewpoint" by Dr. Powell
"Trancedence of e" by Mr. Hunter
"Theory of Games" by Dr. Lionel Weiss
"Continued Fractions" by Mr. Peterson

The annual initiation was held on April 30, 1957. Thirty-two new members were initiated. In addition to the initiation ceremony the DeCou prizes of $50.00 each were presented to B. A. Bloomfield and P. Williams.

Officers for 1956-57 were: Director, R. R. Fossum; Vice-Director, D. Marshall; Secretary-Treasurer, N. K. Kim.

Officers for 1957-58 are; Director, J. Denton; Vice-Director, E. A. Barrett; Secretary-Treasurer, L. Hinrichs.

GAMMA OF OHIO University of Toledo

The Ohio Gamma Chapter held three meetings during 1956-57. The first one was a business program meeting. Dr. C. W. Thompson was the speaker. The second meeting was the initiation banquet. Five new members were inducted at this time. Dr. Craig was the speaker. His topic was "History of the Development of Logic." The third meeting was an outing.

Officers for 1957-58 are: Director, Dr. Shoemaker; Vice-Director, William Frederick; Secretary, Carl Hutter; Treasurer, Richard Marleau.

ALPHA OF LOUISIANA, Louisiana State University

The Louisiana Alpha Chapter held two business meetings, two program meetings and the initiation banquet during 1956-57. Thirty new members were initiated. Dr. Haskell Cohen was the banquet speaker. The following papers were presented during the year:

"The Life and Work of Sir Isaac Newton" by Ali Tangoren
"What is Mathematics" by Dr. Richard D. Anderson

The Freshman Award, based on an honors examination, was won by Frank A. Richey, Jr. The Senior Award, selected by the Department of Mathematics, was won by William P. Girod.

Officers for 1957-58 are: Director, Ali Tangoren; Vice-Director, Aristide E. Ton; Secretary, L. Jane Smart; Treasurer, Robert T. Smart; Faculty Advisor, Dr. Haskell Cohen; Corresponding Secretary, Dr. Houston T. Kames.

INITIATES

ALABAMA ALPHA, University of Alabama (May 4, 1957)

John P. Beaulieu	Charles Arthur Gross	Charles M. Pyron, Jr.
Jane E. Brownlee	Mike Rhodes Hauser	Beverly June Ryan
Ronald F. Callaway	William Mathes House	Jerome K. Redus
William W. Clements	Fred H. Hudoff	William C. Snoddy
Bunny Crawford	Carl W. Johnson	William Jackson Stone
Ernest Farrier	Gerald L. Kilgore	O. Eugene Thomas, Jr.
Donald E. Fitts	Emily J. Longshore	Walter D. Trippe
Kelly V. Grider		Howard B. Wilson, Jr.

ALABAMA BETA, Alabama Polytechnic Institute (May 16, 1957)

Robert T. Agee, Jr.	William H. Golden	Gerald D. Myrick
Elizabeth Baskerville	Cecil G. Hefner, Jr.	George M. Peace
John A. Burdeshaw	John M. Herman, Jr.	Robert W. Phillips
Phillip Randolph Carter	Kieth M. Howie	Charles N. Prosch
Bryant T. Castellow II	Henry G. Jackson	Robert L. Savage
Lewis Carl Covan	M. B. Jackson	James Michael Scarborough
Thomas H. Daugherty	John K. Jones	Nora Frances Smith
James Edward Dupree	Mary Celia Jones	Josh Walling, Jr.
Lucis Mahlon Dyal, Jr.	William H. McCorvey	Wayne N. Williams

ARIZONA ALPHA, University of Arizona (April 12, 1957)

Farid F. Abraham	Jan Hunsaker	Bernard Oppenheim
Roberta Abrahams	Carolyn Jensen	Robert Piserchio
Richard Barrett	James E. King	Harry Rainey
Rodney H. Bell	Richard Lee	William E. Rushton
Maurice W. Collins	William W. Lynch	John Simley
Robert H. Dickerson	Royal D. Miller	Robert Steenbergen
William D. Fortner	Charles Moore	James B. Sutton
Jack Gaines	Patrick Moss	Robert Williamson
William H. Herndon	Evar D. Nering	Irvin S. Yavelberg

CALIFORNIA ALPHA, University of California (June 1, 1957)

Kenneth Samuel Davis	Ichiro Hashimoto	Maria Van't Riet
Robert David Engel	Sister Margaret Leo	Herbert Takashi Suyematsu
Tom Fong	Richard A. Maxwell	Martin Vangerov
Marcel Gawartin	John S. Mizushima	Victor W. Wirship
	Georgia Pahos	

CALIFORNIA GAMMA, Sacramento State College (Charter Members) (May 23, 1957)

Robert L. Alves	George Kondos	John M. Powell
Joseph Chan	Richard P. Lundahl	Ray D. Scanlon
Neil R. Cull	Chester H. McIntosh	Gerald C. Smith
Deon T. Fowles	Vladimir Moss	Richard B. Tanner

(Members initiated on the occasion of the installation of the chapter)

Ross Brown	Gordon Glabe	Bill D. Munselle
Sadao Dairiki	Philip Mishler	John L. Wulff

COLORADO BETA, University of Denver (November 30, 1956)

Robert Lorance Beer	Frank Richard Hammond	Ronald Maxwell Ross
Carl Frederick Berger	Robert Eugene Johnson	Ivan Dean Stones
Jean Ann Fischer	Don Evard Lee	Fred P. Venditti
Donald Edwin Fraser	Frank Edward Leslie	Walter John Williams
William Bryant Gragg		Daniel Kershner Wolfe

FLORIDA ALPHA, University of Miami (April 12, 1957)

Frederic Borges,	Mary Jean Leslie Leithh	Samuel Miller
Rolando Mario Cuenca	John Louzader	Daniel Morgan, Jr.
Fred Luther Fuller	Emmet Francis Low	Fred Rudow
Sandra Annette Green Stone	Homer Lloyd Lowe	Wilhelm Schmidt
Albert Holloway	Basil Marotta	Richard Paul Trissell
Olga Latoni	Anne Louise Meyer	Jack Pacifico Zarzar

FLORIDA BETA, Florida State University (May 20, 1957)

William Blumen
James Francis Brooks
Richard E. Chandler
Charles J. Croteau
Wade H. Greene, Jr.
Sara Elizabeth Hardy
Albert L. LeDuc, Jr.
Hansel B. Mead, Jr.
Joe Neggers
S. Zane Pinckney
Bobby Lee Sanders
Louis Sica
Ted Thomas
Mary Margaret Williams

GEORGIA ALPHA, University of Georgia (May 3, 1957)

Richard S. Bell
Benjamin Lewis Brinson, Jr.
Ernest H. Drew
John P. Gill, Jr.
Frank Themell Phillips
Winslow Rodeck Remley
Ronald K. Spence
Gilbert H. Walker

ILLINOIS ALPHA, University of Illinois (May 21, 1957)

Donald Henry Abernathie
Samuel Israel Baker
Steven Fred Bauman
Felix Anton Beiner
John Andrew Berton
William Edmond Bicknell
James Robert Boen
Shirley May Berfield
Ernest Robert Buley
Carl Ernest Carlston
Lena Chang
Sabita Chatterjie
Cheng Lon Chen
Richard Ross Chesnutt
Ralph Willard Christison
Addison Gilbert Cook
Robert Davis Cook
Dennis Frank Cudia
Mary E. Cunningham
Samarendra M. Das Gupta
James LeRoy Divilbiss
hiasao Doyama
Norman Marvin Edelstein
Robert Earl Eggers
John Joseph Ehrlich
John Robert Ehrman
Garlie A. Forehand
Fred Thomas Forman
Clinton Ross Foulk
Henry Frandsen
Charles William Gear
Richard Gramman
Ronald Dean Hartwick
David Fults Herberer
Richard Bruce Hickman
Harold Joseph Horne
Albert Inselberg
Howard Lawrence Jackson
Vivian L. Johnson
Frederick Dsuin Ju
Musa Rasim Kamal
Robert Lee Kelley
William Hayes Kirchhoff
Charles Frederick Koch
Kenneth Dean Kugler
Aivars Kuplis
Doris Kay Lapp
Gary Leaf
Michael Jerry Levine
Wataru Mayeda
Frederick Louis Minn
John Martin Mountz
Otis Granville Peterson
Donald Arthur Pierre
Christopher Pottle
Nageswari Rajaratnan
Robert William Resek
Harold Eugene Ray
Alvin LaVerne Schlage
James Edwin Schlosser
Frederick Harold Shair
Robert Carter Sine
John David Steben
Roland Stemmler
James Tasi
Richard James Tector
Joyce Carolyn Totten
Carl (Chang Tao) Wang
Monica Jean Wyzalek
Petros D. Zavitsanos

ILLINOIS BETA, Northwestern University (May 22, 1957)

Ronald Paul Andres
Howard R. Bagwell, Jr.
Virginia Carlton
Jean E. Fanning
Vance A. Fisher
Frederic J. Forrester
Robert Paul Foss
Eugene John Gehrig
Thomas J. Johnson
John A. Jossi
Morris Jurkowitz
Virgil Kelley
Arnold D. Kerr
Claude Olson
Roger L. Peterson
Stephen Lee Propeck
Robert Henry Ramey, Jr.
Vernon Reisenleiter
Stanley J. Rudnick, Jr.
Wes Ernest Sanders
Elmer L. Scheuerman
Karen Schroeder
Lindsay A. Skinner
Charles Stepkin
Charles E. W. Ward
Marilyn J. Woodyard
Ronald Zeman

ILLINOIS DELTA, Southern Illinois University (May 31, 1957)

Dennis Lang Bechtlofft
Floyd W. Bowen
Pauline Brigham
Riad R. Daqqaq
Francis O'Bryan Davis
Ronald Ray Ganschinietz
Joyce Anne Hart
James A. Howell
Janet E. Messerli
Donald B. Parker
David Edward Phillips
Frederick W. Zurheide

IOWA ALPHA, Iowa State College (April 30, 1957)

Mary Ellen Anderson
Paul M. Anderson
Henry Clay Ballantyne
Alfred C. Beckwith
Henry Gilbert Bray
Hubert Burroughs
Torcom Chorbaijian
Leslie L. Cochran
Joe D. Cunning
Kenneth Deckart
Arlington M. Fink
Robert F. Grossman
Paul A. Haeder
Paul M. Harms
Richard L. Hummel
William L. Kennedy
Scott A. Krane
Joe P. LaPlante
George W. Melton, Jr.
Maynard L. Moe
Roderick D. Riggs
Thomas J. Robinson
Stephen Rohrbaugh
Terry Allen Smay
Richard O. Stenerson
Lyle Herman Taylor
David H. Thompson
Clark Marcus Varnum
William Lee Waltman
William F. Ward

IOWA ALPHA (Continued)

John E. DonCarlos
Larry E. Efferding
Bertrand T. Fang
John R. Paulat
Marilee Anne Payne
Lyle Walter Rachuy
Peter Donald Wetrich
William C. Woody
Delbert F. Wright

KANSAS ALPHA, University of Kansas (April 13, 1957)

Jack Lee Beal
John Edgar Beam
John David Conch
Charles R. Deeter
Daniel G. Dewey
Broocke Eubank
James Ewbank
Edward D. Gaughen
Dianne P. Hays
Arnold L. Janousek
Carmelita Keyes
Janice Mae Kibler
Paul W. Liebnitz
Shirley T. Loeven
Mildred A. Long
Greta S. Mack
Kenneth L. Montgomery
Joan Nance
Edwin L. Petrik
Wilma I. Roberman
Sharon Steele
Donald Lee Sturgis
Barbara A. Weir

KANSAS BETA, Kansas State College (May 1, 1957)

John C. Brooks
James L. Carlstedr
Charles A. Halijak
Thomas L. Hamilton
Jack Harris
Eugene M Hughes
Ralph T. Johnson
Robert Leroy Kirkpatrick
William F. McBratney
Theron D. Oxley, Jr.
Harry O. Posten
Laura Louise Smith
Koichiro Tsunewaki
Patricia A. Tucker
Stanley Wearden

KANSAS GAMMA, University of Wichita (May 15, 1957)

Walter D. Bernhart
Theodore Bleicher
Nickander James Damaskos
Larry Verne East
David Melvin Henderson
Leonard Ray Murphy
Jerry Nicholson
Inez Sausen
Calvin Schwartzkopf

LOUISIANA ALPHA, Louisiana State University (May 16, 1957)

Jack H. Allison
Ralph W. Amos, Jr.
Louis P. Andrews
Jan P. Bergeron
Robert M. Brooks
Carolyn Campbell
T. G. Carley
Vivian M. Carvajal
Jenola Googe
Balfour W. Goree, Jr.
Harold W. Gourgues, Jr.
Edward W. Graham
Donald W. Hecker
Yvonne Hunter
Gerald E. Jeansonne
Ann Percy Kurts
Donald J. Lartigue
Sam H. Lott, Jr.
Robert E. Neubaum
J. Tinsley Oden
Louis Jennings Owens
Jackie Pullig
Tobin Robertson
Bill Rowen
I. J. Sherman, Jr.
James G. Shipley, Jr.
Jane Smart
Robert Thomas Smart
A. E. Ton
Francis J. Weingartner

MARYLAND ALPHA, University of Maryland (May 26, 1957)

Mirian Bernhardt
Derrill Bordelon
Chester C. Dodson, Jr.
Paul Frederickson
Alan Gilbert Henney
Yukao Hsu
Dora E. Kearney
Robert C. Kline, Jr.
Marilynn Morton
Tom Paley
Robert M. Sorensen
Gordon T. Trotter
Howard Wilson
Walter R. Wise

MISSOURI ALPHA, University of Missouri (May 2, 1957)

Patricia A. Andresen
Joyce A. Apostal
Earl L. Bennett
Adwain L. Bush
Melvin D. Clark
Charles Wayne Cook
Robert E. Dodge, Jr.
Marvin Dale Elston
Phillip W. Entsminger
Neal Eugene Foland
Robert G. Gottlieb
Melvin L. Griffith
Philip Clerk Henry
Carl J. Holstein, Jr.
Daniel B. Hutchison
Howard Clayton Illig
Thomas Patrick Kilker
Donald Gene Killian
Richard Joe King
Irvin S. Klaus
David Allan Lee
Don K. McCool
Bernard Joseph McKelvey
Robert W. Magruder
David Hubbard Miller
James Eugene Monsees
Charles Ralph Morton
Roland Leon Parrish
Harold Lee Patrick
John Bruce Prater
Lyle Gordon Rhea
Donald Gene Ridgeway
John D. Slocum
George W. Zobrict

NEBRASKA ALPHA, University of Nebraska (May 19, 1957)

Gary Carl Anderson
Maurice Dean Anderson
Thomas David Anderson
Jeremiah Paul Farrell
William Glen Gingles
Jon Stanley Hargleroad
Robert Keith Otnes
Merlin Kent Parsons
Chester Arthur Sautter

NEBRASKA ALPHA (Continued)

Jerrold William Bebernes
Donald C. Cox
Jere Allan De Vilbiss
Wayne Dale Faber
Dale Eugene Hedman
William Roger Kampfe
Charles Edward Kress
Ronald Bruce Lantz
Norman E. Miller
Keith William Schrader
Malvern Keith Seagren
Gregory Eugene Stillman
Larry Lee Warnke

NEVADA ALPHA, University of Nevada (May 30, 1957)

Dennis Ross Bernotski
Bruce E. Capron
William H. Hadley, Jr.
Harlan Holladay
Thomas W Mark
Walter E. Mientka
James M. Phalan
Frank E. Price
Robert Stratton
Robert N. Tompson
Eugene L. Wahl

NEW HAMPSHIRE ALPHA, University of New Hampshire (November 14, 1956)

Dona Louis Cauchon
James Douglas Cowie
Robert Joseph Desmond
James Ernest Donahue
Bruce Robert Dow
John Clendenin Eckels
Thomas H. Eichelberger
David Gordon Fox
Richard Stanley Goudette
Patrick Joseph Greene
Constantinas J. Katsikas
Dorthy Karandanis
Stephanie Gail Lavender
Fred J. Lorenzen, Jr.
William S. Neal
David Ellsworth Patch
Margaret Ann Shea
Mary Phyllis Todt

NEW YORK ALPHA, Syracuse University (April 2, 1957)

Murray Abramson
Leonard B. Adler
David L. Berry
Glendon H. Bibbins
Vincent Ciamprone
William C. Ciamprone
Mary Ehlers Doscher
Robert G. Hiller
Joel L. Israel
George J. Kunzelman, Jr.
Albert C. McDowell
Rajendra P. Nanavati
Sondra F. Osipow
Samuel Patton
Edward S. Pierson
John V. Ryff
John J. Sand
Warren L. Simmons
Nancy J. Smith
Edward R. Thornton
Francisco E. Torregrosa
Richard D. Wilkins
Joseph H. Yamaoka

NEW YORK GAMMA, Brooklyn College (April 12, 1957)

Noreen Caggiano
Diane Canter
Paul Goldstein
Sidney Heller
Joyce Hoffman
Barbara King
Ellen Lorber
Norman Padnos
Rosalie Simon
Raymond Stone

NEW YORK ETA, University of Buffalo (April 10, 1957)

Ruth H. Adamsky
Ronald J. Benice
Bruce L. Chilton
Robert Edie
Howard T. Humphrey
Albert Jircitano
Leon M. Lewandowski
Judith K. Neifach
Donald J. Persico
Rollin T. Sandberg
Samuel Stern

NORTH CAROLINA ALPHA, Duke University (Spring 1957)

Charles Leland Bassett
Robert Carroll Beaty
Howard Hillel Berman
Richmond Wiley Bourne, Jr.
Fred Oscar Brownson
Carol Annette Cleave
Ralph H. Clinard, Jr.
Rollin Thaddeus Curran
Charles Henderson Dickens
Harriet Jane Drawbaugh
Priscilla Irene Edson
Sherri Rhoda Forrester
Robert Henry Greene
Clara Katheryne Hale
Julius King
Richard Alan MacEwen
William Thomas Peters
Karl Bock Peterson
Stephen Gary Rudisill
William Oran Suitar, Jr.
Nipit Sutan-Tanon
Bruce Carroll Tyson, Jr.
Charles Joseph Wine
James Godfrey Woolery
Joseph Andrew Yura

OHIO ALPHA, University of Ohio (May 15, 1957)

Bernard S. Albert
Albert W Beatty, Jr.
Albert B. Bishop III
Margaret Blue
James H. Brann
Dickson H. Call
Kwo-Chang Cheng
Ta-Shing Chu
J. Robert Collier
Robert J. Garbacz
Joseph F. Garibotti
Stanley E. Harrison
Billy Joe Henkener
Nickolas C. Herbert
Paul G. Hershall
Frank C. Holden
Mark Hopkins
James A. Jordan, Jr.
J. Fred Leetch
James H. McMicking
Roger E. Mills
David M. Nitzberg
Terence P. O'Malley
Stuart Lee Petrie
Clarence W. Pitman
Abul F. M. A. Raship
Luther D. Rudolph

OHIO ALPHA (Continued)

Robert S. Cooper
William Raymond Cowell
Julius Dohnanyi
Franklin E. Eastep
Richard C. Erdman
Truman G. Foster
Dawon Kahng
Peter D. Kennedy
Thomas J. Kozik
Daniel J. Krause
Jen Kai Kuo
Stewart K. Kurtz
Ausma Skerbele
Robert A. Stein
Raphael Tsu
E. Roderick White
Ramon Edgar Wolfe
Eugene Yang

OHIO DELTA, Miami University (May 9, 1957)

Charles Richard Cothern
Beverly A. Griffith
Sue Lashley
Jack Allen Metcalf

OHIO EPSILON, Kent State University (May 22, 1957)

Charlotte Kibler
William John Leonard, Jr.
David Calvin Rausch

OKLAHOMA ALPHA, University of Oklahoma (May 7, 1957)

Jon Cole
Allen S. Davis
Bill Freeman
Dale B. Furlow
Patrick A. Highland
Douglas N. Johnson
Donna C. Joplin
Philip Kibby
Riley Needham
Thomas Gilbert Norris
Grady Ward Paxton, Jr.
Bill Purvis
Charles Richard Quade
William A. Sibley
Gustavus James Simmons
Daryl F. Southard
Dale Young

OREGON ALPHA, University of Oregon (April 30, 1957)

David M. Barnhart
Eamon B. Barrett
A. T. Bharucha-Reid
Tong Cheong Cheah
Te Tse Chang
Sei Yong Cho
Percy M. Cuttle
Yvonne G. Cuttle
Marybelle Davis
James Q. Denton
Lawrence C. Eggan
Samuel N. Greenschlag
Lowell A. Hinrichs
James H. Jordan
Patrick J. Judd
Charles E. Land
Giles W. Maloof
Clarence A. Oster
Stanley S. Page
Ponnuswam R. Pakshrajan
Barbara A. Poole
James C. Puscas
James L. Shinn
Carl R. Shonk
David L. Sylwester
Douglas R. Thayer
Donald L. Von Buskirk
Lionel Weiss
Howard L. Wiener
Patsy A. Williams
Ralph A. Wilson
Robert L. Zimmeran

OREGON BETA, Oregon State College (May 27, 1957)

Gilbert Arthur Bachelor
Bert Elwood Brown
Lamar William Coleman
Roger Allen Crawford
William Edward Fasnacht
Jerome Woodruff Finnigan
Robert Paul Going
Kenneth Gerald Hadley
Alva Merle Jones
Henry Ralph Kaiser
Shinzo Kodama
Prithvi Chand Lall
Chih Chiang Lo
Charles Robert Mullen
Gary Arthur Pearson
Julian M. Pike
John G. Skinner
Alan Lee Stockett
Jack Loren Teague
George Gallaway Town
Kosaku Uyeda
John E. Vinson
Bryan Dale Walker

PENNSYLVANIA DELTA, Pennsylvania State University (May 18, 1957)

Stephen Behman
Webb T. Comfort
Glenn W Cumblidge
Charles S. Duris
Harold R. Gongloff
Howard S. Hall
James Irwin
Leo W. Lemley
Herbert Million
David M. Rockmore
Walter A. Sillars
Gervydas Simaitis
Ian B. Strong

PENNSYLVANIA EPSILON, Carnegie Institute of Technology (May 22, 1957)

Donald Boyce Davis
Alexander J. Federowicz
Robert Martin Fitzgerald
Marvin Lowell Graham
David Guy Hill
Robert John Justine
Young Suh Kim
Regis Francis Leonard
Louis Carl Marquet
Richard F. McDermot
Edwin Henry Rogers
John Kenneth Russell
Ernest H. Shin
Nicholas J. Sopkovich
James Anthony Voytuk
Robert Lindner Goodrich

VIRGINIA ALPHA, University of Richmond (January 14, 1957)

Mariett Carolyn Ayers
Donald Edward Boyer
Mary Jane Freed
Victor Frederick German
Edwin Aylette Mayo
George Rodney Myers

VIRGINIA ALPHA (Continued)

Nancy Jane Cyrus
Richard Owen Delap, Jr.
Reginald John Exton
Frances Elizabeth Gray
John Emmett Jenkins
Mary Alice Revere
Elizabeth Elford Smith
Charles Ray Tolbert

WASHINGTON BETA, University of Washington **(May 28, 1957)**

Joseph A. Betz
William E. Bonnice
Donald T. Cottingham
Ann Marie Fauchold
James R. Guard
Gloria Hewitt
R. B. Hora
Paul Hsu
Howard Inouye
Douglas L. Johnson
Masami Kono
William H. Martin
Joseph L. Nolan
Robert Q. Petersen
Benjamin M. Prince
James D. Reid
Harold E. Richardson
Kenneth A. Ross
Ronald A. Schaufele
Ann Schnatterly
Julie A. Setzer
Harley D. Stanard

WISCONSIN BETA, University of Wisconsin (May **21, 1957)**

Richard Austing
James R. Carter
Jule Ann Hansen
Ruth L. Hinkins
Helen Ward Jansen
William M. Lambert, Jr.
D. Russell McMillan, Jr.
Margaret L. Murphy
Thomas H. Nack
Herbert J. Rebassoo
Gertrude Watling
Malcolm C. Whatley

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