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MATHEMATICS AND COMPUTING PANEL

QUARTERLY PROGRESS REPORT

FOR

THE PERIOD ENDING JULY 31, 1949

A. S. HOUSEHOLDER, CHIEF

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MATHEMATICS AND COMPUTING PANEL QUARTERLY PROGRESS REPORT for the Period Ending July 31, 1949

A. S. Householder, Chief

Date Issued: NOV 17 1949

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MATHEMATICAL PANEL
QUARTERLY REPORT TO AUGUST 1, 1949

Alston S. Householder, Chief

Two new members have joined the Panel since the writing of the last report. These are Dr. M. L. Nelson, formerly of NEPA, and Mr. Carl Perhacs, who came to Oak Ridge from Pittsburgh, Pennsylvania. Dr. Nelson, who joined the Panel on May 2, will be in charge of computing, and is continuing work begun at NEPA relating to methods of shield computations. Mr. Perhacs, who arrived April 18, is at present in training on the IBM equipment at Y-12.

Besides these additions to the permanent staff, Mr. T. W. Mullikin, a former member of the Mathematics Section who left to continue his academic training, has joined the Panel for the summer months; and Mr. Robert Lewis, on loan from NEPA, has been rendering valuable assistance on the xenon and other problems.

The Association for Computing Machinery met in Oak Ridge on Monday, Tuesday and Wednesday, April 18, 19, and 20. All meetings were held at the Oak Terrace, and meals were served at the same place. For those arriving on Sunday, coffee and cookies were served that afternoon and evening at Claremont Hall, where most of the guests were housed. Special events included a bus tour of the Area Monday afternoon, a banquet Monday evening, tea on Tuesday afternoon at the American Museum of Atomic Energy, a demonstration of the new IBM 604 multiplier by Mr. F. C. Uffelman and his group, and a smoker Tuesday evening.

Total registration numbered 245, and the following organizations (outside of Oak Ridge and not including the University of Tennessee) were represented:

ORGANIZATIONS

AEC, Washington
Air Force
Alabama Polytechnic Institute
American-Swedish Board
Argonne National Laboratory
ARMA Corporation
Army Department
Army Map Service
Australia, University of Sydney
Ballistic Research Laboratory
Barber-Colman Company
Bell Aircraft Corporation
Bell Telephone Laboratories
Berkeley, E.C. and Associates
Bureau of Budget
Bureau of Census

Bureau of Ordnance
Burroughs Adding Machine Company
Cambridge Field Station, USAF
Consultant, Burlington, Vt.
Consulting Electrical Engineer, Brooklyn
Cornell Aeronautical Laboratory
Eastman Kodak Company
Eckert-Mauchly Computer Corporation
Engineering Research Association
Florida University
Franklin Institute
General Electric
Georgia School of Technology
Gulf Research and Development
Harvard University
IBM, New York
IBM, Washington
Illinois University
Johns Hopkins University
Kellex Corporation
Kentucky University
Little, Arthur D. Company
Manufacturer's Research
Massachusetts Institute of Technology
Mellon Institute
Metropolitan Life Insurance Company
Michigan University
Munitions Board
Mutual Life Insurance Company
NACA, Cleveland
Naval Ordnance Laboratory
Naval Proving Ground
Naval Research Laboratory
N. B. S., Los Angeles
N. B. S., Washington
Newton Company
Nielsen, A. C. Company
North Carolina State College
North Carolina University
Northrop Aircraft
Office of Air Research
Office of Naval Research
Ohio State University
Pennsylvania University
Planning Research Division, USAF
Prudential Insurance Company
RAND Corporation
Raytheon Manufacturing Company
R.C.A., Camden
R.C.A. Laboratories
Remington Rand, Inc.
Sig. Corps Eng. Lab.
Social Security Administration
Sperry Gyroscope
Sylvania Electric Company
Texas University
USAF Comptroller
U. S. Navy Department
Vanderbilt University
Weather Bureau

The complete program is as follows:

SESSION I -- *Presiding:* Dr. John W. Mauchly, *Eckert-Mauchly Computer Corporation*

Address of Welcome	Dr. A. M. Weinberg *Oak Ridge National Laboratory*
Limitations of Electronic Digital Computing Machines	Dr. Edward W. Cannon *National Bureau of Standards*

Analogue and Special Purpose Computing Machines	Professor S. H. Caldwell *Massachusetts Institute of Technology*

SESSION II -- *Presiding:* Dr. Mina Rees, *Office of Naval Research*

Inversion of Large Matrices	Dr. Gertrude Blanch *National Bureau of Standards*
Problems in Linear Programming	Mr. Emil Schell *Office of the Air Comptroller, USAF*
Computing Machinery in Australia	Professor T. G. Room *University of Sydney, Australia*

SESSION III -- *Presiding:* Dr. C. C. Hurd, *International Business Machines Corporation*

Statistical Theory of Round-Off Errors	Dr. H. D. Huskey *National Bureau of Standards*
The Relations of Symbolic Logic and Large-Scale Calculating Machines	Mr. Edmund C. Berkeley *Edmund C. Berkeley and Associates*
Calculation of Neutron Age by Monte Carlo	Dr. A. S. Householder *Oak Ridge National Laboratory*
Computing Statistical Atomic Fields on the Selective Sequence Electronic Calculator	Dr. L. H. Thomas *Watson Laboratory, IBM*

SESSION IV -- *Presiding:* Dr. John H. Curtiss, *National Bureau of Standards*

Binary Notation in Arithmetic Algorithms and Operation Code Partitions	Mr. E. F. Cheydleur *Naval Ordnance Laboratory*
602A Calculating Punch-Time Saver in Computing Thermodynamic Properties of Gases	Mr. Jack Belzer Mr. H. L. Johnston Miss Lydia Savedoff *Ohio State University*
The Register Code for the Eniac	Dr. R. F. Clippinger Dr. B. Dimsdale Dr. George Reitweismer *Aberdeen Proving Ground*
Recent Progress on Selectron	Dr. Jan Rajchman *Radio Corporation of America*

SESSION V -- *Presiding:* Dr. H. H. Aiken, *Computation Laboratory, Harvard University*

The Philosophy of Computing Machine Design	Dr. George R. Stibitz *Consultant in Applied Mathematics* *Burlington, Vermont*

Internal Conversion Calculation on Mark I	Dr. M. E. Rose *Oak Ridge National Laboratory* Dr. Bernard Spinrad *Argonne National Laboratory*
Experience with the Use of the Aiken Relay Calculator	Dr. Clarence Ross *Naval Proving Ground*
Logical Design of Direct-Coupled Vacuum Tube Control Circuits	Mr. Theodore Kalin *Computation Laboratory* *Harvard University*

SESSION VI -- *Presiding:* Dr. Franz L. Alt, *National Bureau of Standards*

The Statistical Mechanics of High Polymers	Dr. Gilbert W. King *Arthur D. Little, Inc.*
An Intercomparison of Storage Devices	Dr. S. N. Alexander *National Bureau of Standards*
The NBS Interim Computer	Dr. Samuel Lubkin *National Bureau of Standards*

A Symposium on the Monte Carlo Method was held at Los Angeles on June 29 and the two days following. This was sponsored jointly by the Institute for Numerical Analysis, and the Rand Corporation, with the cooperation of the Oak Ridge National Laboratory. Members of the Committee on Arrangements were:

John H. Curtiss, *National Bureau of Standards*
Hallett H. Germond, *RAND Corporation*
Alston S. Householder, *Oak Ridge National Laboratory*
Cuthbert C. Hurd, *International Business Machines Corporation*
Raymond P. Peterson, *National Bureau of Standards*

Objectives of the conference were several-fold. The Monte Carlo method originated and received its initial development within the AEC laboratories. Nevertheless the method and many of the results of its application have been declassified, and while it is potentially a method of wide applicability, virtually nothing has appeared on the subject in the open literature. Moreover, there has been little opportunity for those who have been employing the method to exchange notes and ideas on techniques. And finally, both Rand and the Institute have engaged a number of mathematicians to spend the summer in Los Angeles to explore the range of problems for which the method might prove useful, especially, types of differential equations, and it was hoped that the meetings might provide an orientation for them.

The Institute for Numerical Analysis has agreed to publish the proceedings, members of the Committee on Arrangements serving as editors. In view of the rapid developments in the field it is recognized that the value of the publication will be transient at last. Consequently an early fall deadline has been set.

The complete program follows:

SESSION I -- ORIENTATION
Presiding, J. H. Curtiss, *National Bureau of Standards*

The Monte Carlo Method	S. Ulam *Los Alamos Scientific Laboratory*
Discussion	J. von Neumann *Institute for Advanced Study*

SESSION II -- PHYSICAL APPLICATIONS OF STOCHASTIC METHODS
Presiding, J. von Neumann, *Institute for Advanced Study*

Showers Produced by Low Energy Electrons and Photons	Robert R. Wilson *Cornell University*
Nomograms for Monte Carlo Solution of the Milne Problem	B. I. Spinrad *Argonne National Laboratory* G. H. Goertzel *New York University*
Neutron Age Calculations in Water, Graphite, and Tissue	A. S. Householder *Oak Ridge National Laboratory*
Methods of Probabilities in Chains Applied to Particle Transmission through Matter	Lewis Nelson *Oak Ridge National Laboratory* Wendell DeMarcus *NEPA Project, Fairchild Engine and Airplane Corporation*
Multiple-Scattered Rays	Ugo Fano *National Bureau of Standards*
Stochastic Methods in Statistical Mechanics	Gilbert W. King *Arthur D. Little Company*

SESSION III -- PHYSICAL APPLICATIONS OF STOCHASTIC METHODS (Continued)
Presiding, Frank C. Hoyt, *Argonne National Laboratory*

Calculations on a Water Shield for Fast Neutrons, I	Maria Mayer *Argonne National Laboratory*

Calculations on a Water Shield for Fast Neutrons, II	Preston Hammer *Los Alamos Scientific Laboratory*
A Monte Carlo Technique for Estimating Particle Attenuation in Bulk Matter	B. A. Shoor *Northrop Aircraft, Incorporated* Lewis Nelson *Oak Ridge National Laboratory* Wendell DeMarcus Robert L. Echols *NEPA Project, Fairchild Engine and Airplane Corporation*
Neutron Transmission through Thick Slabs	Williston Shor *U. S. Navy*
Estimation of Particle Transmission by Random Sampling	Herman Kahn T. E. Harris *RAND Corporation*

SESSION IV -- RANDOM DIGITS
Presiding, Jerzy Neyman, *University of California*

Generation and Testing	George W. Brown *RAND Corporation* Nicholas Metropolis *Los Alamos Scientific Laboratory* George E. Forsythe *National Bureau of Standards*
Various Techniques Used in Connection with Random Digits	J. von Neumann *Institute for Advanced Study*
General Discussion from the Floor	

SESSION V -- MATHEMATICAL SESSION
Presiding, John W. Tukey, *Princeton University*

The Connection between Stochastic Processes and Partial Differential Equations	William Feller *Cornell University and the National Bureau of Standards* Mark Kac *Cornell University and the National Bureau of Standards* J. L. Doob *University of Illinois*
Discussion from the Floor	

SESSIOI VI -- ROUND TABLE DISCUSSION: CRITIQUE OF APPLICATIONS AND DISCUSSION OF POSSIBLE NEW DIRECTIONS FOR RESEARCH

Presiding, John W. Tukey, *Princeton University*

Panel: J. Neyman, *University of California*
M. A. Girschick, *Stanford University*
W. A. Wallis, *University of Chicago*
D. H. Blackwell, *Howard University*
T. W. Anderson, *Columbia University*
L. J. Savage, *University of Chicago*

Papers by members of the Panel were presented at both of the meetings discussed above. On April 29 the American Mathematical Society and the Biometric Society met jointly at Lawrence, Kansas, and Householder presented an invited paper discussing some preliminary results on the isotope-diffusion problem described below. The same paper was presented at the School of Aviation Medicine, Randolph Field, and at Tulane University. A paper on the fitting of exponential decay curves (see below) was presented at the University of Oklahoma on May 2. And a paper entitled "Some Numerical Methods of Solving Systems of Linear Equations" has been accepted for publication by the American Mathematical Monthly.

The Summer Work Session on Shielding has called for contributions from the Panel, both technical and organizational. Members of the Panel participated in planning the program, and are participating in the mathematical and computational phases as reported below. In connection with the former aspect, Professor von Neumann spent three days at the Laboratory advising as to appropriate computational techniques and apparatus.

It seems well worth reporting that at the request of NEPA and the Air Force and also on the Laboratory's own account, an examination of the present development of high speed computing machinery was made. P. R. Bell of the Physics Division, A. S. Householder and Lewis Nelson of the Mathematics Panel visited the RCA Laboratory in Princeton, New Jersey, on July 12, the Computing Machinery Laboratory of the Institute for Advanced Study in Princeton on July 13, the Eckert-Mauchly Computing Machinery Corporation in Philadelphia on July 14, and the National Bureau of Standards in Washington, D. C. on July 15, 1949.

E. E. St. John and Wendell DeMarcus of NEPA visited the last three named laboratories along with the ORNL representatives. Subsequently E. E. St. John, P. R. Bell and A. S. Householder visited the Raytheon Corporation in Waltham, Massachusetts, and revisited the Bureau of Standards.

Early in August the above named are to meet with ORNL, NEPA, and AEC representatives for the purpose of formulating a jointly acceptable plan for

(i) acquiring (or not acquiring) a high speed computer for the common use of interested Oak Ridge Laboratories.

(ii) arranging for use of an existing machine until one becomes available in Oak Ridge.

The detailed listing of technical problems follows:

Problem: Diffusion of radioactive isotopes in multicompartmental biological systems.

Origin and Background: See previous Report

Participating Member of Panel: A. S. Householder

Status: The differential equations and their solution were described in the previous Report, for the case of a finite number of compartments. The problem was then to generalize to the case of a large number of compartments whose exchange rates could be characterized by a statistical distribution function, and to relate the parameters of this distribution to the form of the curve $a_0(t)$ representing the decline in radioactivity in the "outer" compartment.

The generalization is made as follows: One defines a step function $A(\alpha)$ to satisfy

$$
\begin{aligned}
A(\alpha) &= 0, & \alpha &< \alpha_1, \\
&= A_1, & \alpha_1 &\leq \alpha < \alpha_2, \\
&= A_1 + A_2 & \alpha_2 &\leq \alpha < \alpha_3 \\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
&= A_1 + A_2 + \cdots + A_n, & \alpha_n &\leq \alpha.
\end{aligned}
$$

and another, $X(u)$, to satisfy

$$
\begin{aligned}
X(u) &= 0, & u &< \lambda_1, \\
&= x_1, & \lambda_1 &\leq u < \lambda_2 \\
&= x_1 + x_2, & \lambda_2 &\leq u < \lambda_3 \\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
&= x_1 + x_2 + \cdots + x_n, & \lambda_n &\leq u,
\end{aligned}
$$

where the quantities α_i, A_i, λ_i, and x_i were defined previously. Then the definition

$$g(\lambda) = 1 - \int_0^\infty (\lambda - \alpha)^{-1} \, d\, A(\alpha)$$

has meaning in either the continuous or discontinuous case, as does expression

$$a_0(t) = x_0 + \int_0^\infty \exp(-ut) \, d\, X(u)$$

which reduces to the solution previously obtained for the discontinuous case. The functions $X(u)$ and $A(\alpha)$ are related by

$$[\lambda\, g(\lambda)]^{-1} = x_0/\lambda + \int_0^\infty (\lambda - u)^{-1} \, d\, X(u).$$

It is convenient to introduce the related function $B(\alpha)$, to replace $A(\alpha)$, by

$$d\, A(\alpha) = \alpha \, d\, B(\alpha), \qquad B(0) = 0.$$

Then the moments X_r and B_r of the functions $X(u)$ and $B(\alpha)$ are defined by

$$X_r = \int_0^\infty u^r \, d\, X(u), \qquad B_r = \int_0^\infty \alpha^r \, d\, B(\alpha),$$

and they satisfy the recursion relations

$$
\begin{aligned}
X_1 &= B_1, \\
X_2 &= X_1 B_1 + B_2, \\
X_3 &= X_2 B_1 + X_1 B_2 + B_3, \\
&\cdots\cdots\cdots\cdots\cdots\cdots \\
X_r &= X_{r-1} B_1 + X_{r-2} B_2 + \cdots + B_r, \\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots
\end{aligned}
$$

These relations can be transformed to express the mean and the statistical moments about the mean of either distribution in terms of those of the other one. A sequential calculation would not be difficult, though in explicit form the relations are complex.

Of particular interest experimentally is the fact that if x is the mean and ν_r the r-th statistical moment about the mean of the distribution X(u), one can write

$$a_0(t) - x_0 = X_0 \; C(t) \qquad \exp(-xt)$$

where

$$C(t) = 1 + \tfrac{1}{2} \nu_2 t^2 - \tfrac{1}{6} \nu_3 t^3 + \tfrac{1}{24} \nu_4 t^4 \ldots \; .$$

If we set

$$C(t) = \exp c(t)$$

then

$$c(t) = \tfrac{1}{2} \nu_2 t^2 - \tfrac{1}{6} \nu_3 t^3 + \tfrac{1}{24} (\nu_4 - 3 \nu_2^2) t^4 + \ldots \; .$$

represents the divergence from linearity on a semi-log plot. This means that on a semi-log plot of $a_0(t) - x_0$, the initial slope is determined by the mean of the distribution X(u) and the initial curvature by its variance. The same statement can be made with respect to the mean and variance of the distribution $B(\alpha)$ since this mean and variance are, respectively,

$$b = x_0 \; x, \qquad b_2 = x_0 \; \nu_2 \, .$$

Problem: Fitting exponential decay curves.

Participating Members of the Panel: A. S. Householder, R. R. Coveyou, Donna Palmiter

Background: Analytical methods for fitting exponential decay curves would find application in several branches of science. In physics and chemistry the experimental values are theoretically expressible as linear combinations of exponentials with constant coefficients. In biology certain types of multiple-hit curves appear to be representable as the product of a single exponential and a polynomial. Other, more complex, cases are possible.

Generally fits are made visually on semi-logarithmic plots. This is relatively quick and easy but has the obvious disadvantage that no measure of divergence can be assigned. A mechanizable analytical procedure that can be carried out automatically, that will provide a criterion for the number of terms required, and that will provide a measure of the adequacy of the representation, is much to be desired.

A report was prepared some time ago and is now in the hands of the typist, which describes among other things a method that solves the problem formally, and that, moreover, reduces the multiple-hit problem to one of the same type. The method is an adaptation of a very old method of Prony. The modification consists essentially in adjusting the sequence of calculations in such a way that one can, in principle, test sequentially the adequacy of the sum of one term, two terms, three terms, etc. After each test the calculations can be used either as a basis for proceeding to the next, or, as the coefficients of a certain algebraic equation, the logarithms of whose roots are the required decay constants.

Status: A preliminary test of the method by applying it to artificial data seems to indicate that it is excessively laborious and unduly sensitive to the statistical fluctuations and errors of measurement. The problem is continued, however, in the hope that either the apparent difficulties of the method can be circumvented, or some better method will present itself.

Problem: Development of phage in a bacterial suspension.
Origin and Background: See previous Report
Participating Members of Panel: A. S. Householder, Donna Palmiter
Status: Some numerical integrations of the differential equations have been performed and will be presented later in a memorandum. Other problems of greater urgency have made it necessary to discontinue work on this one, at least for the present.

Problem: Statistical analysis of effects of body irradiation of rats.
Origin and Background: See previous Report
Participating Members of Panel: A. S. Householder and Donna Palmiter
Status: The statistical analysis has been completed and the results are being published by Dr. Kohn.

Problem: Monte Carlo estimate of neutron collision densities in tissue from high energy sources.

Origin and Background: See previous Report

Participating Members of Panel: N. M. Dismuke, R. R. Coveyou, M. R. Arnette, A. S. Householder

Status: Calculations on the IBM have been started, but interrupted in order to do the analysis of the xenon data.

Problem: Statistical analysis of X-10 dispensary visits.

Origin and Background: See previous Report

Participating Member of Panel: A. S. Householder

Status: The original problem called for obtaining the regression of frequency of dispensary visits on a number of independent variables, including one set representing place of longest residence and one set representing place of education. It was decided to eliminate the set corresponding to place of education because of its virtual identity with place of longest residence.

The matrix which then required inverting had an 11 × 11 identity submatrix, and the inverse was therefore expressible in terms of the inverse of a matrix of order about 25. Inversion of this matrix is now under way.

Problem: Statistical analysis of bloodcounts of X-10 employees.

Origin and Background: See previous Report.

Participating Member of Panel: A. S. Householder

Status: The problem is now almost entirely in the hands of the statistical group at K-25. Panel participation consists of only occasional consultation.

Problem: Analysis of results of Monte Carlo estimates of collision densities of neutrons in water.

Participating Members of Panel: A. S. Householder, T. W. Mullikin

Origin, Background and Status: Previous reports have described two Monte Carlo calculations of collision densities and energy losses of neutrons in water, in one case from a 25 Kev source and in the other from a 35 Kev source. A report is being prepared describing and analyzing the results in detail.

Problem: Methods of probabilities in chains applied to particle transmission through matter.

Origin: Mr. Wendell C. DeMarcus, NEPA, and Dr. Lewis Nelson

Participating Member of Panel: Lewis Nelson

Background: While Nelson was employed at NEPA he and DeMarcus undertook the problem here described. It was completed after Nelson's employment at ORNL and is to appear as a NEPA report.

To compute the attenuation of a steady state beam of neutrons incident on an infinite slab of finite thickness the following considerations were made. The phase space with coordinates distance (into the slab), energy, and direction was divided into a finite number of cells. The cells are numbered serially and the average probability a_{ij} that a neutron in cell j will be in cell i directly after it has made one collision is computed. Layers of fictitious cells (traps) are adjoined to the outer face of the slab, and to the inner face for those whose direction coordinate return neutrons to the source. Each of these cells and each of that layer of cells whose energy coordinate is the lowest a neutron is permitted is given probability unity that a neutron remains in it once the particle reaches that state.

If A is the matrix of elements a_{ij} and V_o is the column vector which gives the neutron distribution of the source, distribution after every neutron has suffered k collisions is given by

$$V_k = A^k V_o .$$

In the limit as k becomes infinite the steady state distribution is given by

$$V^* = A^* V_o$$

where A^* is lim (A^k) as k becomes infinite.

Status: The paper demonstrates the existence of a unique A^* under an ergodic hypothesis that a particle not in a trap has non-zero probability of reaching a trap in finitely many collisions. It is further shown that the form of A^* is such that its elements can be computed by solving the equation

$$A^* A = A^*$$

and this is virtually reduced to inverting u matrices each of order N where

u ≡ number of different energy states allowed

N ≡ number of cells, for a fixed energy, which are not traps.

A simple problem has been solved with a reasonable amount of computing time and with reasonable results. However, the solution of a general problem requires so much time that the method is probably not practical without use of a genuinely high speed computer.

Problem: A Monte Carlo shielding experiment.
Origin: The Summer Work Session on Shielding
Participating Member of Panel: Lewis Nelson
Background: With H. Kahn of RAND and the Summer Work Session and other members of the session, a Monte Carlo problem has been designed. The actual computations are expected to be performed at K-25 by Mr. J. P. Kelly and the IBM staff there. As the problem is designed, a plane source of monoenergetic (10 Mev) neutrons will diffuse through a three-dimensionally infinite media of water.

The source will be directionally distributed so that by proper analysis the results can be interpreted in terms of an arbitrary directional distribution of source particles. Only one of the geometric coordinates will be recorded.

1200 particles are to be followed. These are divided into three groups of 400 each. The scattering by hydrogen will be sampled from a distribution which is biased toward forward scattering, thus effectively sampling the high energy neutrons. The amount of the bias will vary from group to group.

The exponential transformation will be made on one of the neutron groups. In addition, the life history of each neutron of each group will be subjected to an integration over the geometric coordinate of its first collision, thus increasing the efficiency of the method.

All biased samplings will be corrected by application of proper weights.

From the computations estimates will be made of the effect of small changes in the ratio of hydrogen to oxygen, of using "smooth" cross sections, and of the various sampling distributions chosen. Estimates of such quantities as the neutron flux across planes variously separated from the source will be made.
Status: The problem is in the process of discussion with the IBM group at K-25 preparatory to the actual computations.

Problem: Analysis of scintillation spectrometer data.
Origin: Mr. P. R. Bell and group, Physics Division
Participating Members of Panel: A.S. Householder, R.R. Coveyou, T.W. Mullikin, and Lewis Nelson

Background: The scintillation spectrometer measures a function f(x) of the energy spectrum F(y) of a gamma or beta ray beam. When x and y are given in units which are appropriate to the spectrometer, these functions are related by the integral equation

$$f(x) = \int_{-\infty}^{\infty} e^{-(x-y)^2} F(y)\, dy$$

where f(x) is an even function.

Status: In an effort to solve the above integral equation, it is assumed that $F(y) \equiv 0$, $Y \leqslant |y|$. The corresponding integral is replaced by a (Riemann) sum with constant spacing Δ in y. For $x_j = j\Delta$, $j = -p, \ldots, -1, 0, 1, \ldots, p$, the integral equation is thus approximated by the simultaneous linear equations

$$\sum_{k=-p}^{p} e^{-\Delta^2 (j-k)^2} \phi(k\Delta)\, \Delta = f(j\Delta).$$

If the substitution

$$a \equiv e^{-\Delta^2}$$

is made, the matrix of these equations is of the form

$$M_n(a) = (m_{rs}) \qquad r, s = 1, \ldots, n$$

$$m_{rs} = a^{(r-s)^2} .$$

This matrix has been inverted in closed form for arbitrary n and a. The inverse of order thirty for a particular a has been computed. It has not yet been applied.

Problem: Effect of radiation on crossing-over in *Drosophila*.
Origin: Dr. Maurice Whittinghill, Biology Division.
Participating Member of Panel: E. A. Forbes
Status: Computation of percentages and standard errors were made. The work has been finished.

Problem: Internal conversion.
Origin: Dr. M. E. Rose, Physics Division
Participating Members of Panel: M. K. Hullings, T.W. Mullikin, N. M. Dismuke, R. R. Coveyou, M. L. Nelson, A. S. Householder, Donna Palmiter

Background and Status: Following the basic calculations for the K-shell on the Mark I at Harvard, a series of interpolation and other calculations have been performed under Dr. Rose's direction, and are elsewhere reported by him. At the same time preparations for L-shell calculations are under way. This involves certain preliminary hand computations and IBM computations to test out the possible routines. Negotiations for time on a sufficiently fast machine have begun.

Problem: Least-squares analysis of decay curves through a series of absorbers.
Origin: Dr. M. Feldman, Chemistry Division.
Participating Member of Panel: M. K. Hullings
Status: Work completed.

Problem: Range of fission fragments.
Origin: Dr. W. M. Good, Physics Division
Participating Member of Panel: M. K. Hullings
Status: Work completed.

Problem: Plotting $(\phi/\phi_{pair})\ k^{-3}\ (1-2p/k \cos\theta)^{-4} \sin^2\theta$ for several values of k.
Origin: Mr. C. D. Moak, Physics Division
Participating Member of Panel: M. K. Hullings
Status: Work completed.

Problem: Penetration of slow neutrons in tissue.
Origin: Dr. W. S. Snyder, Health Physics Division
Participating Member of Panel: K. M. Martin
Status: This required successive numerical approximations to the solution to the Milne problem by a technique developed by Dr. Snyder. The work is completed.

Problem: Calculations of cloud chamber tracks.
Origin: Mr. C. D. Moak, Physics Division
Participating Member of Panel: K. M. Martin
Status: Work completed.

Problem: Survival curves for irradiated spores of *Aspergillus*.
Origin: Dr. W. A. Arnold and Mr. G. E. Stapleton, Biology Division

Participating Members of Panel: Donna Palmiter, A. S. Householder
Status: This problem required curve-fitting by a partly trial-and-error method. The work is completed.

Problem: Statistical analysis of data on the Hilsch tube.
Origin: W. G. Stone, Biology Division
Participating Members of Panel: Donna Palmiter, A. S. Householder
Status: The problem consisted of testing the statistical significance of certain differences. The work is completed.

Problem: Numerical integration.
Origin: Dr. S. M. Dancoff, Physics Division
Participating Member of Panel: Donna Palmiter
Status: Work completed.

Problem: Calculation of γ-ray transmission through a shield by use of an energy-group approximation.
Origin: Dr. T. A. Welton, Shielding Work Session
Participating Member of Panel: T. W. Mullikin
Status: Work completed.

Problem: Xenon cross sections.
Origin: Drs. M. M. Shapiro and Seymour Bernstein, Physics Division
Participating Members of Panel: All members
Background and Status: A considerable fraction of the computing time of the section has, during the last quarter, been absorbed by a least squares analysis of the data obtained in the experiment (Bernstein, et al) performed to determine the cross section of Xe^{135}. The transmission (ratio of neutrons received to neutrons transmitted) of their sample is, because of the short half-life of Xe^{135}, a function both of time and of energy; thus

$$1)\quad T = T_0 \exp[-\sigma(E)\, X(t)], \text{ or}$$

$$2)\quad -\log T = -\log T_0 + \sigma(E)\, X(t) \text{ where}$$

T = transmission factor of sample plus material,

T_0 = transmission factor of sample holder plus carrier, without active material.

$\sigma(E)$ = cross section of Xe^{135} as function of energy,

$X(t)$ = number of Xe^{135} atoms/$(cm)^2$ at time t.

In theory, X(t) is given by the formula:

$$X(t) = \frac{\lambda I_0}{\lambda - \mu} [e^{-\mu t} - e^{-\lambda t}],$$

where

λ = decay constant of I^{135}

μ = decay constant of Xe^{135}

I_0 = number of I^{135} present/$(cm)^2$ at time of preparation of (presumably) xenon-free sample. Because of certain suspected irregularities in the data, it was decided to fit the function X(t) to the observed data according to the assumptions that

a) t, be the time since separation, is not precisely known, and

b) any possible leakage of Xe^{135} from the sample was regular, and proportional to the amount of Xe present.

The result of (b) is to effectively increase its Xe decay constant. If we write

$$-\log T = -\log T_0 + \frac{\lambda I_0 \sigma (E)}{\lambda - \mu} [e^{-\mu(t-t_0)} - e^{-\lambda(t-t_0)}],$$

we see that, for a given experiment, we have the following parameters to adjust:

1) μ
2) t_0
3) $I_0 \sigma(E)$, for each energy measured in run
4) $-\log T_0$, for each energy measured in run.

In general, 3-5 energies were chosen for measurement during each run. Hence, we have 8-12 parameters to estimate. There were about 8 runs with results consistent enough to use. Each run then demands the setting up and solution of a set of 8-12 linear equations in as many unknowns, and, since the equation above is not linear, the process demands

a) Reliable initial estimates of the parameters involved

b) An unspecified number of repetitions of the above described solutions of sets of linear equations.

The above program was attempted, using the IBM equipment at Y-12. However,

reasonable convergence of the process seems not to be achievable, for reasons which are not now understood. Possibilities are:

a) machine error

b) accumulation of round-off error, either in calculation of matrix elements or in inversion

c) failure of the original estimates to lie within the "convergence region" of the problem. Meanwhile, further hand computations seemed to show that the desired results could be achieved by a step-wise estimation and correction of the relevant parameters. This process is being used, again by hand.

It is proposed, after this part of the procedure is completed, then to fit the calculated cross sections to a Breit-Wigner curve, in the form

$$\sigma(E) = \frac{A\,\Gamma\,(E_0/E)^{1/2}}{4(E-E_0)^2 + \Gamma^2},$$

$$\Gamma = \Gamma_\gamma\,(1 + \omega\,[E/E]^{1/2}) \quad ,$$

in which A, E_0, Γ_γ are parameters to be estimated, while ω will be fixed throughout each calculation. Then that value of ω will be selected which gives the best fit to the observed data. This procedure has been adopted because it is felt that the experimental data are relatively insensitive to $\omega = \Gamma_n/\Gamma_\gamma$ and a direct determination of this ratio by least squares would lead to ambiguous results. This conclusion is supported by the results of previous tentative calculations. This last part of the calculation has been adopted on the advice of Dr. Eugene Feenberg.