

THE ANNALS of MATHEMATICAL STATISTICS

FOUNDED AND EDITED BY H. C. CARVER, 1930-1938

EDITED BY S. S. WILKS, 1938-1949

THE OFFICIAL JOURNAL OF THE INSTITUTE
OF MATHEMATICAL STATISTICS

Contents

	PAGE
Charles Jordan, 1871-1959.....	L. TAKÁCS 1
Statistical Methods in Markov Chains.....	PATRICK BILLINGSLEY 12
The Frequency Count of a Markov Chain and the Transition to Continuous Time	I. J. GOOD 41
On the Asymptotic Distribution of the "Psi-Squared" Goodness of Fit Criteria for Markov Chains and Markov Sequences.....	B. R. BHAT 49
Some Properties of Regular Markov Chains.....	B. R. BHAT 59
Some Tests for Categorical Data.....	V. P. BHAPKAR 72
Tables for Unbiased Tests on the Variance of a Normal Population.....	JAMES PACHARES 84
Asymptotic Efficiency of Certain Locally Most Powerful Rank Tests.....	JACK CAPON 88
The Nonparametric Ordering: (1001) \rightarrow (0110).....	JOHN S. WHITE 101
The Non-Central Multivariate Beta Distribution.....	A. M. KSHIRSAGAR 104
A Unified Theory of Estimation, I.....	ALLAN BIRNBAUM 112
Admissible and Minimax Estimates of Parameters in Truncated Spaces	MORRIS W. KATZ 136
The Method of Moments Applied to a Mixture of Two Exponential Distributions	PAUL R. RIDER 143
Snowball Sampling.....	LEO A. GOODMAN 148
Probability Content of Regions Under Spherical Normal Distributions, III: The Bivariate Normal Integral.....	HAROLD RUBEN 171
Recurrent Games and the Petersburg Paradox.....	HERBERT ROBBINS 187
Consistency and Limit Distributions of Estimators of Parameters in Explosive Stochastic Difference Equations.....	M. M. RAO 195
First Emptiness of Two Dams in Parallel.....	J. GANI 219
The Transient Behavior of a Coincidence Variate in Telephone Traffic.....	P. D. FINCH 230
First Passage Times of a Generalized Random Walk.....	JOHN R. KINNEY 235
Identifiability of Mixtures.....	HENRY TEICHER 244
An Asymptotic Formula for the Differences of the Powers at Zero.....	I. J. GOOD 249

(Continued on back cover)

Vol. 32, No. 1 — March, 1961

THE ANNALS OF MATHEMATICAL STATISTICS

Subscription Rates. Current issues are \$15 per volume (four issues of one calendar year) in the U. S. and Canada, \$10 per volume elsewhere. Single issues are \$4. Back numbers for all issues up to and including 1956 (Vol. XXVII) are \$12 per volume, \$3.50 per issue, \$200 for the first 25 volumes, \$10 per additional volume purchased at the same time as Volume I through XXV.

Rates to members of the Institute of Mathematical Statistics are lower (see inside back cover).

Communications concerning **subscriptions, back numbers, payment of dues, etc.**, should be addressed to Gerald J. Lieberman, Treasurer, Institute of Mathematical Statistics, Department of Statistics, Stanford University, Stanford, Calif.

Communications concerning **membership, changes of address, etc.**, should be addressed to George E. Nicholson, Jr., Secretary, Department of Statistics, University of North Carolina, Chapel Hill, N. C. Changes of address which are to become effective for a given issue of the *Annals* should be reported to the Secretary on or before the 10th of the month preceding the month of issue.

Editorial Office, Department of Statistics, Eckhart Hall, University of Chicago, Chicago 37, Illinois. William Kruskal, Editor.

Preparation of manuscripts. Manuscripts should be submitted to the editorial office. Each manuscript should be typewritten, double spaced, with wide margins at sides, top, and bottom, and the original should be submitted with one additional copy, on paper that will take corrections. Dittoed or mimeographed papers are acceptable only if completely legible. Footnotes should be reduced to a minimum, and where possible replaced by remarks in the text, or a bibliography at the end of the paper; formulae in footnotes should be avoided. References should follow current *Annals* style, and should be numbered alphabetically according to authors' names.

Figures, charts, and diagrams should be professionally drawn on plain white paper or tracing cloth in black India ink twice the size they are to be printed.

Authors are asked to keep in mind the typographical difficulties of complicated mathematical formulae. The difference between capital and lower-case letters should be clearly shown; care should be taken to avoid confusion between such pairs as zero and the letter O, the numeral 1 and the letter l, numeral 1 used as superscript and prime ('), alpha and a, kappa and k, mu and u, nu and v, eta and n, etc. Subscripts or superscripts should be clearly below or above the line. Bars above groups of letters (e.g., $\overline{\log x}$) and underlined letters (e.g., \underline{x}) are difficult to print and should be avoided. Symbols are automatically italicized by the printer and should not be underlined on manuscripts. Boldface letters may be indicated by underlining with a wavy line on the manuscript; boldface subscripts and superscripts are not available. Complicated exponentials should be represented with the symbol exp. In writing square roots the fractional exponent is preferable to the radical sign. Fractions *in the body of the text* (as opposed to displayed expressions) and fractions occurring in the numerators or denominators of fractions are preferably written with the solidus; thus $(a + b)/(c + d)$ rather than $\frac{a + b}{c + d}$.

Authors will ordinarily receive only galley proofs. Fifty reprints without covers will be furnished free. Additional reprints and covers will be furnished at cost.

Mail to the *Annals of Mathematical Statistics* should be addressed to either the Editor or the Treasurer, as described above. It should *not* be addressed to Waverly Press.

COMPOSED AND PRINTED AT THE
WAVERLY PRESS, INC., BALTIMORE, MARYLAND, U. S. A.

Second-class postage paid at Baltimore, Maryland

EDITORIAL STAFF

EDITOR

WILLIAM KRUSKAL

ASSOCIATE EDITORS

ALLAN BIRNBAUM
DOUGLAS G. CHAPMAN
W. S. CONNOR

DONALD A. DARLING
WASSILY HOEFFDING
N. L. JOHNSON

OSCAR KEMPTHORNE

E. L. LEHMANN

WITH THE COOPERATION OF

J. R. BLUM	CYRUS DERMAN	C. H. KRAFT	J. W. PRATT
R. C. BOSE	J. L. DOOB	SOLOMON KULLBACK	HOWARD RAIFFA
D. L. BURKHOLDER	MEYER DWASS	EUGENE LUKACS	WALTER L. SMITH
W. S. CONNOR	D. A. S. FRASER	INGRAM OLKIN	LIONEL WEISS
	SAMUEL KARLIN		

PAST EDITORS OF THE ANNALS

H. C. CARVER, 1930-1938	T. W. ANDERSON, 1950-1952
S. S. WILKS, 1938-1949	E. L. LEHMANN, 1953-1955
T. E. HARRIS, 1955-1958	

Published quarterly by the Institute of Mathematical Statistics in March,
June, September and December.

IMS INSTITUTIONAL MEMBERS

ABERDEEN PROVING GROUNDS, BALLISTIC RESEARCH LABORATORIES, Aberdeen, Maryland
AEROJET-GENERAL CORPORATION, P. O. Box 296, Azusa, California
AMERICAN VISCOSE CORPORATION, MARCUS HOOK, Pennsylvania
ATLANTIC REFINING COMPANY, 2700 Passyunk Avenue, Philadelphia, Pa.
BELL TELEPHONE LABORATORIES, INC., TECHNICAL LIBRARY, 463 West Street, New York 14,
New York
BENDIX AVIATION CORPORATION, 1200 Fisher Bldg., Detroit, Michigan
BOEING AIRPLANE COMPANY, Box 3707, Seattle, Washington
CALIFORNIA RESEARCH CORPORATION, P. O. Box 1627, Richmond, California
CASE INSTITUTE OF TECHNOLOGY, STATISTICAL LABORATORY, Cleveland 6, Ohio
CATHOLIC UNIVERSITY OF AMERICA, STATISTICAL LABORATORY, MATHEMATICS DEPARTMENT,
Washington, D. C.
C-E-I-R, Inc., 1200 Jefferson Davis Highway, Arlington 2, Virginia
COLUMBIA UNIVERSITY, DEPARTMENT OF MATHEMATICAL STATISTICS, New York 27, N. Y.
CORNELL UNIVERSITY, MATHEMATICS DEPARTMENT, Ithaca, New York
FORD MOTOR COMPANY, P. O. Box 2053, Dearborn, Michigan
GENERAL ELECTRIC COMPANY, Building C37, Room 248, Schenectady, New York
INDIANA UNIVERSITY, THE LIBRARY, Bloomington, Indiana
INTERNATIONAL BUSINESS MACHINES CORPORATION, MATHEMATICS AND APPLIED SCIENCE
LIBRARY, 1271 Avenue of the Americas, New York 20, N. Y.
IOWA STATE UNIVERSITY, STATISTICAL LABORATORY, Ames, Iowa
LOCKHEED AIRCRAFT CORPORATION, ENGINEERING LIBRARY, Burbank, California
MICHIGAN STATE UNIVERSITY, DEPARTMENT OF STATISTICS, East Lansing, Michigan
MINNESOTA MINING AND MANUFACTURING COMPANY, APPLIED MATHEMATICS AND STA-
TISTICS, St. Paul, Minnesota
MONSANTO CHEMICAL COMPANY, 800 North Lindbergh Blvd., St. Louis 66, Missouri
NATIONAL CASH REGISTER COMPANY, RESEARCH DEPARTMENT, Main and K Streets, Day-
ton 9, Ohio
NATIONAL SECURITY AGENCY, Fort George G. Meade, Maryland
NORTHWESTERN UNIVERSITY, DEPARTMENT OF MATHEMATICS, Evanston, Illinois
PRINCETON UNIVERSITY, DEPARTMENT OF MATHEMATICS, SECTION OF MATHEMATICAL
STATISTICS, Princeton, New Jersey
PURDUE UNIVERSITY LIBRARIES, Lafayette, Indiana
OKLAHOMA STATE UNIVERSITY, DEPARTMENT OF MATHEMATICS, Stillwater, Oklahoma
RADIO CORPORATION OF AMERICA, R.C.A. LABORATORIES LIBRARY, Princeton, New Jersey

(Continued on next page)

RAMO-WOOLRIDGE CORPORATION, Los Angeles, California
REMINGTON RAND—UNIVAC DIVISION, 315 Park Avenue South, New York 10, N. Y.
SANDIA CORPORATION, Sandia Base, Albuquerque, New Mexico
SOCONY MOBIL OIL COMPANY, INC., 150 E. 42nd Street, New York 17, New York
SOUTHERN METHODIST UNIVERSITY, MATHEMATICS DEPARTMENT, Dallas 5, Texas
SPACE TECHNOLOGY LABORATORIES, P. O. Box 95001, Los Angeles 45, California
STANFORD UNIVERSITY, GIRSHICK MEMORIAL LIBRARY, Stanford, California
STATE UNIVERSITY OF IOWA, Iowa City, Iowa
UNION CARBIDE CORPORATION, 30 East 42nd Street, New York 17, New York
UNION OIL COMPANY OF CALIFORNIA, UNION RESEARCH CENTER, Box 76, Brea, California
UNITED STATES STEEL CORPORATION LIBRARY, Monroeville, Penna.
UNIVERSITY OF CALIFORNIA, STATISTICAL LABORATORY, Berkeley, California
UNIVERSITY OF ILLINOIS, SERIALS DEPARTMENT, Urbana, Illinois
UNIVERSITY OF MICHIGAN, DEPARTMENT OF MATHEMATICS, Ann Arbor, Michigan
UNIVERSITY OF NORTH CAROLINA, DEPARTMENT OF STATISTICS, Chapel Hill, North Carolina
UNIVERSITY OF PUERTO RICO, SCHOOL OF TROPICAL MEDICINE, San Juan, Puerto Rico
UNIVERSITY OF WASHINGTON, LABORATORY OF STATISTICAL RESEARCH, Seattle, Washington
W. R. GRACE AND COMPANY, RESEARCH DIVISION, Washington Research Center, Clarks-
ville, Maryland
W. R. GRACE AND COMPANY, DEWEY AND ALMY CHEMICAL DIVISION, 62 Whittemore Avenue,
Cambridge 40, Massachusetts