

# 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
Optimal experimental designs . . . . . SAMUEL KARLIN AND WILLIAM J. STUDDEN	783
A stochastic characterization of wear-out for components and systems Z. W. BIRNBAUM, J. D. ESARY AND A. W. MARSHALL	816
Some properties of statistical reliability functions SIV CARLSSON AND ULF GRENANDER	826
Invariant probabilities for certain Markov processes LESTER E. DUBINS AND DAVID A. FREEDMAN	837
Dimensional properties of a random distribution function on the square J. R. KINNEY AND T. S. PITCHER	849
A local limit theorem for a certain class of random walks . . . WALTER A. ROSENKRANTZ	855
Limit theorems for stopped random walks—II . . . . . R. H. FARRELL	860
A limit theorem for passage times in ergodic regenerative processes . . JULIAN KEILSON	866
Negative dynamic programming . . . . . RALPH E. STRAUCH	871
Comparisons of some two stage sampling methods AARON S. GOLDMAN AND R. K. ZEIGLER	891
A problem in minimax variance polynomial extrapolation . . . . . A. LEVINE	898
Contributions to sample spacings theory, I: limit distributions of sums of ratios of spacings . . . . . SAUL BLUMENTHAL	904
Contributions to sample spacings theory, II: tests of the parametric goodness of fit and two-sample problems . . . . . SAUL BLUMENTHAL	925
On the Pitman efficiency of one-sided Kolmogorov and Smirnov tests for normal alternatives . . . . . P. V. RAMACHANDRAMURTY	940
Exact power of Mann-Whitney test for exponential and rectangular alternatives GEORGE E. HAYNAM AND ZAKKULA GOVINDARAJULU	945
The sequential compound decision problems with $m \times n$ finite loss matrix J. VAN RYZIN	954
Repetitive play in finite statistical games with unknown distributions . . J. VAN RYZIN	976
On the distribution of the largest latent root and the corresponding latent vector for principal component analysis . . . . . T. SUGIYAMA	995

*(Continued on back cover)*

---

Vol. 37, No. 4—August 1966



# THE ANNALS OF MATHEMATICAL STATISTICS

**Subscription Rates.** Current issues are \$30 per volume (six issues of one calendar year) in the U. S. and Canada, \$22.50 per volume elsewhere. Single issues are \$5.25. Back numbers for all issues up to and including 1956 (Vol. XXVII) are \$15 per volume, \$4.00 per issue; issues from 1957 through 1964 are \$20.00 per volume, \$5.25 per issue; from 1965 onward. \$30 per volume, \$5.25 per issue. Complete sets (Volumes I-XXVII) are \$250. If additional volumes are ordered at the same time the set is ordered, the price is \$15 for each additional volume. An index to Volumes I-XXXI is available for \$10.

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

Communications concerning **subscriptions, back numbers, payment of dues, membership, changes of address, etc.**, should be addressed to Professor George J. Resnikoff, Treasurer, Department of Statistics, California State College, Hayward, California 94542.

**Papers** to be submitted for publication should be sent to the Editor, D. L. Burkholder, Department of Mathematics, University of Illinois, Urbana, Illinois 61803. **Abstracts and corrected galley proofs** should be sent to the Managing Editor, P. L. Meyer, Department of Mathematics, Washington State University, Pullman, Washington 99163.

**Preparation of manuscripts.** 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 bibliography at the end of the paper; formulae in footnotes should be avoided. References should follow the style of **33** 313-314.

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.,  $\log \bar{x}$ ) 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 are preferably written with the

solidus; thus  $(a + b)/(c + d)$  rather than  $\frac{a + b}{c + d}$ , and  $ab/cd$  rather than  $\frac{ab}{cd}$ .

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, Managing 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 21202 U. S. A.

Second-class postage paid at Baltimore, Maryland 21202

## EDITORIAL STAFF

EDITOR

D. L. BURKHOLDER

ASSOCIATE EDITORS

R. R. BAHADUR  
HERMAN CHERNOFF  
A. P. DEMPSTER  
J. L. DOOB  
SYLVAIN EHRENFELD

G. ELFVING  
JAMES F. HANNAN  
WASSILY Hoeffding  
ALAN T. JAMES

SAMUEL KARLIN  
J. H. B. KEMPERMAN  
E. L. LEHMANN  
RONALD PYKE  
R. A. WIJSMAN

MANAGING EDITOR

P. L. MEYER

PAST EDITORS OF THE ANNALS

H. C. CARVER, 1930-1938	E. L. LEHMANN, 1953-1955
S. S. WILKS, 1938-1949	T. E. HARRIS, 1955-1958
T. W. ANDERSON, 1950-1952	WILLIAM KRUSKAL, 1958-1961
J. L. HODGES, JR., 1961-1964	

Published bimonthly by the Institute of Mathematical Statistics in February,  
April, June, August, October and December.

## IMS INSTITUTIONAL MEMBERS

AEROSPACE CORPORATION, El Segundo, California  
ARIZONA STATE UNIVERSITY, Tempe, Arizona  
BALLISTIC RESEARCH LABS., WEAPON SYSTEM LAB., Aberdeen, Proving Ground, Md.  
BELL TELEPHONE LABORATORIES, INC., TECHNICAL LIBRARY, New York, N. Y.  
BOEING AIRPLANE COMPANY, Seattle, Washington  
CASE INSTITUTE OF TECHNOLOGY, STATISTICAL LABORATORY, Cleveland, Ohio  
CATHOLIC UNIVERSITY OF AMERICA, STAT. LAB., MATH. DEPT., Washington, D. C.  
CHEVRON RESEARCH Co., Richmond, California  
COLUMBIA UNIVERSITY, DEPARTMENT OF MATHEMATICAL STATISTICS, New York, N. Y.  
CORNELL UNIVERSITY, MATHEMATICS DEPARTMENT, Ithaca, New York  
FLORIDA STATE UNIVERSITY, DEPARTMENT OF STATISTICS, Tallahassee, Florida  
FORD MOTOR COMPANY, Dearborn, Michigan  
GENERAL MOTORS CORPORATION, RESEARCH LABORATORIES, Warren, Michigan  
GEORGE WASHINGTON UNIVERSITY, DEPARTMENT OF STATISTICS, Washington, D. C.  
W. R. GRACE AND COMPANY, RESEARCH DIVISION, Clarksville, Maryland  
GRADUATE RESEARCH CENTER OF THE SOUTHWEST, Dallas, Texas  
HUGHES AIRCRAFT COMPANY RESEARCH LABS., Malibu, California  
INDIANA UNIVERSITY, THE LIBRARY, Bloomington, Indiana  
INTERNATIONAL BUSINESS MACHINES CORPORATION, New York, New York  
IOWA STATE UNIVERSITY, STATISTICAL LABORATORY, Ames, Iowa  
KANSAS STATE UNIVERSITY, DEPARTMENT OF STATISTICS, Manhattan, Kansas  
KNOLLS ATOMIC POWER LABORATORY, Schenectady, New York  
LOCKHEED AIRCRAFT CORPORATION, ENGINEERING LIBRARY, Burbank, California  
MICHIGAN STATE UNIVERSITY, DEPARTMENT OF STATISTICS, East Lansing, Michigan  
MINNESOTA MINING AND MANUFACTURING COMPANY, APPLIED MATHEMATICS AND STATISTICS, St. Paul, Minnesota  
MONSANTO CHEMICAL COMPANY, St. Louis, Missouri  
NATIONAL CASH REGISTER COMPANY, RESEARCH DEPARTMENT, Dayton, Ohio  
NATIONAL SECURITY AGENCY, Fort George G. Meade, Maryland  
NORTHWESTERN UNIVERSITY, DEPARTMENT OF MATHEMATICS, Evanston, Illinois  
OHIO STATE UNIVERSITY, STATISTICS LABORATORY, DEPARTMENT OF MATHEMATICS, Columbus, Ohio  
OKLAHOMA STATE UNIVERSITY, DEPARTMENT OF MATHEMATICS, Stillwater, Oklahoma  
PENNSYLVANIA STATE UNIVERSITY, DEPARTMENT OF MATHEMATICS, University Park, Penna.  
PRINCETON UNIVERSITY, DEPT. OF MATH., SECT. OF MATH. STAT., Princeton, New Jersey  
PROCTER & GAMBLE COMPANY, TECHNICAL LIBRARY, Cincinnati, Ohio  
PURDUE UNIVERSITY LIBRARIES, Lafayette, Indiana  
ROCKEFELLER UNIVERSITY, New York, N. Y.  
SANDIA CORPORATION, Sandia Base, Albuquerque, New Mexico  
STANFORD UNIVERSITY, GIRSHICK MEMORIAL LIBRARY, Stanford, California  
SYSTEMS DEVELOPMENT CORPORATION, Santa Monica, California  
TEXAS A & M UNIVERSITY, INSTITUTE OF STATISTICS, College Station, Texas  
TRW SYSTEMS, INC., Redondo Beach, California  
UNION OIL COMPANY OF CALIFORNIA, UNION RESEARCH CENTER, Brea, California  
UNITED STATES STEEL CORPORATION LIBRARY, Monroeville, Pennsylvania  
UNIVERSITY OF ARIZONA, Tuscon, Arizona  
UNIVERSITY OF CALIFORNIA, DEPARTMENT OF MATHEMATICS, Riverside, California  
UNIVERSITY OF CALIFORNIA, STATISTICAL LABORATORY, Berkeley, California  
UNIVERSITY OF ILLINOIS, SERIALS DEPARTMENT, Urbana, Illinois  
UNIVERSITY OF IOWA, Iowa City, Iowa  
UNIVERSITY OF MICHIGAN, DEPARTMENT OF MATHEMATICS, Ann Arbor, Michigan  
UNIVERSITY OF MINNESOTA, DEPARTMENT OF STATISTICS, Minneapolis, Minnesota  
UNIVERSITY OF MISSOURI, DEPARTMENT OF STATISTICS, Columbia, Missouri  
UNIVERSITY OF NORTH CAROLINA, DEPARTMENT OF STATISTICS, Chapel Hill, North Carolina  
UNIVERSITY OF ROCHESTER, Rochester, New York  
UNIVERSITY OF WASHINGTON, LABORATORY OF STATISTICAL RESEARCH, Seattle, Washington  
UNIVERSITY OF WISCONSIN, DEPARTMENT OF STATISTICS, Madison, Wisconsin  
WESTINGHOUSE ELECTRIC CORPORATION, RESEARCH LABORATORIES, Pittsburgh, Penna.