

“अक्षरी पठन् ज्ञानज्योतः”

**NORTH MAHARASHTRA UNIVERSITY,**

**JALGAON - 425 001**

**Syllabus  
FOR M.Sc. (Statistics)  
with effect from July 1994**

**DEPARTMENT OF MATHEMATICAL SCIENCES**

NORTH MAHARASHTRA UNIVERSITY, JALGAON

M.Sc.(STATISTICS)

STRUCTURE

SEMESTER-I

ST 101	:	Calculus and Complex analysis.
ST 102	:	Linear Algebra.
ST 103	:	Sampling theory and methods.
ST 104	:	Probability Distributions.
ST 105	:	Computer Programming and Utilization.

SEMESTER-II

ST 201	:	Applied Probability Models.
ST 202	:	Statistical Inference.
ST 203	:	Multivariate Analysis.
ST 204	:	Theory of Probability.
ST 205	:	Computer Oriented Numerical Methods.

SEMESTER-III

ST 301	:	Linear Models.
ST 302	:	Asymptotic Inference.
ST 303	:	Statistical Process Control.
ST 304	:	Optimization Techniques-I.
ST 305	:	Practicals-I.

SEMESTER-IV

ST 401	:	Stochastic Models.
ST 402	:	Optional I.
ST 403	:	Optional II.
ST 404	:	Optimization Techniques-II.
ST 405	:	Practicals- II.

List of Optional Courses :

1. Time Series Analysis
2. Reliability
3. Applied Regression Analysis
4. Discrete Data Analysis
5. Planning of Industrial Experiments.

ST 101 : CALCULUS AND COMPLEX ANALYSIS.

1. Functions of several variables

Linear transformations of the Euclidean  $n$  - space  
Differentiability of functions of several variables. The  
chain rule. Contraction principle. Partial and directional  
derivatives. Inverse and implicit function theorems.

2. Uniform convergence of sequences and series of functions.  
Weierstrass m-test, power series, radius of convergence.

3. Analytical functions, Power series, expansion of analytic  
function, fundamental theorem of algebra Liouville's  
theorem. Cauchy's theorem.

4. Singularities, Classification of Singularities, poles and  
essential singularities. Singular part Laurent series  
development. Rouché's Theorem

5. Calculus of Residues.

Books Recommended

1. Walter Rudin : Principles of Mathematical Analysis
2. T.M. Apostol : Mathematical Analysis
3. J.V. Deshpande: Complex Analysis.

ST 102 : LINEAR ALGEBRA.

Matrix algebra, special types of matrices, determinants  
and their simple properties.  
Orthogonal and impenitent matrices.

Linear dependence, basis of a vector space, an  
orthogonal basis. Gram-Schmidt orthogonalization,  
linear transformation; Rank of a matrix; Linear  
equations, solution space and null space.

Characteristic roots of real matrices, right and left  
characteristic vectors, independence of characteristic  
vectors corresponding to distinct characteristic roots,  
algebraic and geometric multiplicities; Generalized  
inverse.

Definiteness of a real quadratic form, reduction of  
quadratic forms, simultaneous reduction of two  
quadratic forms, maxima and minima of ratios of two  
quadratic forms.

Books Recommended :

1. Graybill F.E. : Introduction to matrices with  
applications in statistics.
2. Hohn F.E. : Elements of matrix algebra
3. Rao C.R. : Linear Statistical inference and its  
applications.
4. Searle S.R. : Matrix algebra useful for statistics.
5. Bellman R. : Introduction to matrix analysis

ST 103 : SAMPLING THEORY AND METHODS.

Basic methods of sample selection, simple random sampling with replacement, simple random sampling without replacement, probability proportional sampling with and without replacement, systematic sampling, estimation problems, Horvitz - Thompson estimator and its properties.

Stratification : Allocation problems and estimation problems, formation of strata and number of strata, method of collapsed strata. Use of supplementary information for estimation, ratio and regression estimators with their properties and generalizations.

Use of Auxiliary information for estimation, ratio and regression estimators with their properties and generalizations.

Cluster sampling, multi-stage sampling.

Double sampling procedures, uses of ratio and regression estimators, stratifications.

Non-sampling errors, response and non-response errors and their treatments.

Books Recommended

1. Des, Raj : Sampling Theory
2. Murthy, M.N. : Sampling Theory and Methods
3. Sukhatme, P.V. : Sampling Theory of Surveys and  
Sukhatme, B.V. Applications  
Sukhatme, S.B.  
& Ashok C.
4. Daroys Singh : Sampling theory with applications  
& Chaudhary,

ST 104 : PROBABILITY DISTRIBUTIONS.

Bivariate and Multivariate discrete and continuous distributions, Marginal and conditional distributions. Probability Generating functions, Compound distributions (Techniques based on probability generating functions).

Multiple Regression, Multiple and partial correlations. Distribution of linear and quadratic forms in independent, identically distributed, standard normal variables (Techniques based on moment generating functions). Cochran's theorem.

Books Recommended

1. Cramer, H. : Mathematical Methods in Statistics
2. Fisz, H. : Probability and Mathematical Statistics.
3. Hogg, R.V. and  
Craig, A.T. : Introduction to Mathematical Statistics
4. Johnson, N.L.  
& Kotz, S. : Distributions in Statistics: Continuous  
Multivariate Distributions.
5. Rohatgi, V.K. : Introduction to Probability Theory and  
Mathematical Statistics.
6. Feller, W. : Probability Theory and its Applications,  
Vol. 1.

ST 105 : COMPUTER PROGRAMMING AND UTILIZATION-1.

1. Logical organization of computer system, introduction to number systems, introduction to computer programming, Algorithms and flow charts, program development process.
2. Introduction to FORTRAN 77 Character set, data types, expressions, operations, standard functions.
3. Sequential Structures :
  - . Assignment statement
  - . Input and Output statements (list directed)
  - . STOP statement.
  - . END statement
4. Selective Structures
  - . GOTO Statements : Assigned GOTO, Computed GOTO.
  - . IF Statements : Logical IF, Block IF, Arithmetic IF.
  - . Nested block IF structures.
  - . Multi alternative selective structure
5. Repetitive structures
  - . IF Loop
  - . DO Loop
  - . Nested DO Loop
6. Subscripted variables : Notation
  - . ARRAYS
  - . DIMENSION Statement
  - . Input/Output of Arrays
  - . PARAMETER statement
7. Format - Directed Input and Output
  - . Input/Output Statements
  - . FORMAT Statement
  - . Format Specifications
8. Subprograms
  - . Purpose and Use
  - . Functions : Library, Statement, Function subprograms
  - . Sub-routine : CALL Statement
  - . DATA, SAVE, COMMON Statements.
9. File Processing
  - . Opening and Closing of files
  - . Obtaining Information about files
  - . File Input and Output
  - . File positioning
10. Additional Features
  - . PROGRAM Statement
  - . PAUSE Statement
  - . EQUIVALENCE Statement

Utilization

Writing FORTRAN-77 programs for the following.

1. Finding largest/smallest of given numbers using array and without array.
2. For arranging given numbers in Ascending/Descending order using array without array.
3. Matrix Multiplication.
4. To find Transpose of a given Matrix.
5. Find  $\sin(x)$  using Taylor's series and compare the obtained value using standard function.

6. To accept any integer number and write it in reverse order. Also find sum of its digits.
7. Generate first 100 prime number starting from any prime number.
8. Find GCD of given numbers.

#### Books Recommended

1. V. Rajaraman, Computer Programming in FORTRAN 77, PHI (1990)
2. Programming with FORTRAN-77 : Ram Kumar, TMH.
3. Davice & Hofma FORTRAN-77 : A structured Disciplined style, Mc Graw Hill, New York.
4. Kernighan B.W. & Flugter P.J. : Elements of Programming style McGraw Hill, New York.

#### ST 201 : APPLIED PROBABILITY MODELS :

Conditional Probability and Expectations. Problems based on conditional probability Markov chains with stationary transition probabilities, properties of transition functions, classification of states, Stationary distribution of Markov chains, existence and uniqueness, convergence to the stationary distribution.

Markov pure jump processes, Poisson process, birth and Death process. Application to Queuing, Inventory, Machine-Repairmen problems. Elements of time series analysis.

#### Books Recommended

1. Medhi, J. : Stochastic Processes.
2. Feller, W. : An Introduction to Probability Theory and its applications, Vol. I (Third Edition).
3. Karlin, S. : A first course in Stochastic processes & Taylor, H.M. (Second Edition)
4. Hoel, P.C. : Introduction to Stochastic Processes. Port, S.C. & Stone, C.JR.
5. Ross, S. : Introduction to Probability Models.

#### ST 202 : STATISTICAL INFERENCE.

Sufficiency, completeness, and Uniformly minimum variance unbiased estimators, exponential class of densities and its properties, some special classes of densities and its properties, some special classes of distributions admitting complete sufficient statistics, extensions of these results to multi-parameter situations.

Test function, Neymann Pearson lemma for test functions. Uniformly most powerful tests for one sided alternative for one parameter exponential class of densities and extension to the distributions having monotone likelihood ratio property.

Confidence intervals, shortest expected length confidence intervals, relation with testing of hypotheses, uniformly most accurate confidence intervals.

### Reference Books .

1. Dudewics E J. : Introduction to Statistics and Probability.
2. Roussas G.G. : First course in mathematical statistics
3. Silvey S.D. : Statistical inference
4. Wilks S.S. : Mathematical Statistics
5. Lehmann E.L. : Testing of statistical hypotheses.
6. Lehmann E.L. : Theory of point estimation

### ST 203 : MULTIVARIATE ANALYSIS.

Singular and nonsingular multivariate normal distributions, their properties, quadratic forms in multivariate normal vectors.

Maximum likelihood estimators of the parameters of a multivariate normal distribution, their sampling distributions.

Wishart distribution and its properties.

Tests of hypotheses about the mean vector of a multi normal population, Hotelling's T-statistics, its distribution, applications of Hotelling's T.

Maximum likelihood estimators of partial and multiple correlation coefficients, their sampling distributions.

Classification problem (Bayes approach is not expected)  
Discriminant Analysis, Mahalanobis D statistics.  
Introduction to principal component and canonical correlation analysis.

### Books Recommended

1. Anderson T.W. : Introduction to Multivariate Statistical Analysis
2. Kshirsagar A.M. : Multivariate Analysis
3. Morrison D.F. : Multivariate Statistical Method.
4. Rao C.R. : Linear Statistical Inference and its Application
5. Johnson R.A. : Applied multivariate Statistical analysis.  
& Wichern D.W.

### ST 204 : THEORY OF PROBABILITY.

Algebra of sets, fields and Sigma-fields, limits of sequences of subsets, Sigma-fields generated by a class of subsets, Borel fields.

Probability measure on a Sigma field, probability space, continuity of probability measure, real and vector valued random variables, induced probability measure, distribution functions, independence.

Expectation of a random variable, important properties of expectation, Markov and Chebychev inequalities. Characteristic function and their properties.

Sequence of independent random variables, convergence in probability and in quadratic means, weak law of large numbers, convergence in distribution, central limit theorem for independent random variables in Liapunov's form, Cramers theorem in composition of convergence in probability.

### Recommended Books

1. Bhat B.R. : Introduction to mathematical probability theory
2. Chung K.L. : Course in Probability Theory
3. Tucker H.G. : Graduate course in programming
4. Gnedenko B.V. : Theory of probability
5. Loeve M. : Probability Theory

ST 205 : Computer Oriented Numerical Methods.

1. Errors in Numerical Calculations :  
Introduction, Errors and their analysis. A general error formula, error in series approximation.
2. Solution of Algebraic and Transcendental Equations: Introduction, The bisection Method, The Method of False Position, Newton-Raphson Method of iteration.
3. Interpolation :  
Introduction, Errors in Polynomial interpolation, Finite Differences (Forward Differences, Central Differences, Symbolic Relations), Detection of Errors by Use of Difference tables, Lagrange interpolation, Truncation error in interpolation, Newton's formulae for interpolation.
4. Solution of Simultaneous Algebraic Equations :  
Introduction, Matrix Inversion Method, The Gauss elimination method, Pivoting, Illconditioned equations, The Gauss-Seidel iterative method, The Eigenvalue Problem.
5. Numerical Differentiation and Integration :  
Introduction, Formulae for numerical differentiation, Numerical Integration (Trapezoidal Rule, Simpson's 3/8 Rule), Errors in integration formulae.
6. Numerical Solution of Differential Equations  
Introduction, Euler's method, Taylor series, Runge-Kutta methods.

ST 301 : LINEAR MODELS.

Gauss-Markov model, estimability of a linear parametric function, best linear unbiased estimator, Gauss-Markov theorem, Testing of linear hypothesis.

Applications of Gauss-Markov theory for analysis of one and two way designs, completely randomized design, randomized block design, Latin square design, and balanced incomplete block design. Balance, connectedness and orthogonality in relation to two way design. Missing plot technique, analysis of covariance, Factorial experiments, confounding and fractional replication in  $2^n$  factorial experiments.



Books Recommended

1. Kshirsagar, A.M. : Linear Models
2. Searle, S.N. : Linear Models
3. Chakrabarti, M.T. : Mathematics of Design and Analysis of Experiments
4. John, P. W.M. : Statistical Design and Analysis of Experiments
5. Rao, C.R. : Linear Statistical Inference and its Applications
6. Dunn, O.J. and Clark, V. : Applied Statistics
7. Ogawa, J. : Statistical Theory of the Analysis of Experimental Design.
8. A.M. Thampane : Design of experiment

ST 302 : ASYMPTOTIC INFERENCE.

Consistency (mean squared and weak), invariance of consistency under continuous transformation, consistency for several parameters, generating consistent estimators using weak law of large numbers, CAN estimators under differentiable transformations, generation of CAN estimators using central limit theorem.

Methods of moments, method of maximum likelihood, special cases such as exponential class of densities and multinomial distribution, Cramer-Hazurbazar theorem, method of scoring.

Likelihood ratio tests, asymptotic distribution of log likelihood ratio, application including contingency tables.

Books Recommended

1. Cramer, H. : Mathematical Methods in Statistics
2. Rao, C.R. : Linear Statistical Inference and its Applications.
3. Silvey, S.D. : Statistical Inference
4. Wilks, S.S. : Mathematical Statistics.

ST 303 : STATISTICAL PROCESS CONTROL

1. Relation between Theory of Testing hypothesis and control charts, Basic concepts of control of a process and process capability.
2. Control chart for measurements and attributes.  $\bar{X}$ , S, C, P- charts with subgrouping, CUSUM charts, MA charts, EWMA charts, Use of these charts for prediction, CUSUM procedure for controlling process variability, Comparison with Shewart charts, Acceptance control charts.
3. Process capability indices, Determining Pp, and capability computation.
4. Acceptance sampling, usage Forming characterisation by OC curve and ABL, Inspection by variables for one-sided/two-sided specification limits.
5. Discussion on MIL, S.P.S. Standards provided by MIL and ISO, Latest standards - ISO 9000.

6. Multivariate control charts for measurement data.
7. Effect of skewness and kurtosis on level and dispersion, effect of departure from independence.
8. Further theoretical results for CUSUM charts.

#### Books Recommended

1. Ryan, J.P., Statistical Methods for quality improvement, John Wiley, (1989)
2. Westerhill, G.E and Brown, D.W., Statistical Process Control : Theory and Practice, Chapman and Hall (1991)
3. Hansen, E.L. and Garo F.M., Quality Control and Application, Prentice Hall, (1987).
4. John, W.M., Statistical Methods in Engineering Quality Assurance, John Wiley, (1986).
5. Guenther, W.C, Sampling Inspections in Statistical Quality Control, Charta Griffin, (1981)

#### ST 304 : OPTIMIZATION TECHNIQUES-I.

Linear Programming : Graphical procedures; redundant activities, surplus resources; simplex algorithm theory and method; dual of a problem and properties of dual; dual simplex procedure, revised simplex procedure.

Applications of linear programming : transportation problem; assignment problem; maximum flow in a given network; shortest route problem; transshipment problem.

Integer programming: Pure LIPF; Mixed integer programming problem; branch and bound method, f -cut.

#### Book Recommended

1. Hadley, G. : Non-Linear and dynamic programming
2. Taha, H.A. : Operations Research an Introduction
3. Gauss, S.I. : Linear Programming
4. Taha, H.A. : Integer Programming
5. Wagner : Principles of Operations Research
6. Rambo, N.S. : Mathematical Programming Techniques.
7. D.T. Phillips: Operations Research.

#### ST 305 : PRACTICALS - I

Practicals are based on ST 103, ST 102, ST-104

1. Computation of inverse of a given matrix  
(a) natural inverse (b) g-inverse (c) Moore-Penrose inverse.
2. Solving system of linear equations.
3. Computing higher order powers of a given matrix using spectral decomposition.
4. Computation of the largest eigen value of a matrix without solving the determinantal equation. (By Iterative procedure).
5. Generation of random numbers from continuous distributions and mixtures.
6. Generation of random numbers from discrete distributions and mixtures.
7. Regression and orthogonal polynomials.
8. Multiple and partial correlation.
9. Stratified random sampling.
10. Ratio Regression method of estimation.
11. Horvitz Thompson estimators and FPS and  $\pi$  ps designs.

12. Double sampling procedures.

#### ST -401 STOCHASTIC MODELS

1. Elements of Renewal Theory & its applications
2. Theory of Queues :  
Queueing systems M/M/1, M/M/1, M/G/1 and GI/M/1.  
Finite time solution for the system M/M/1, use of M/M/1.  
Use of combinatorial methods in obtaining  $P(t)$  for  
M/M/1. Regenerative points and embedded markov  
chains for the systems M/G/1 and GI/M/1. Stationary  
solution for M/M/1, M/M/1 and M/M/s ladder indices.
3. Inventory Models  
Single item statistics model, model with price breaks,  
multiple item model with storage limitation, single  
item n-period dynamic model, newsboy problem, (S,s)  
policy, application of renewal theory to the (S,s)-  
inventory model, Moran's dam, Rosenblatt's  
grain storage model.

#### Books Recommended

1. Prabhu, N.U. : Queues and inventories, Wiley
2. Prabhu, N.U. : Stochastic storage Processes, Springer  
Verlag
3. Taha, H.A. : Operations Research- An Introduction
4. Tijms, H.C. : Stochastic Modeling and Analysis.
5. Medhi, J. : Stochastic Processes.

ST 402 : OPTIONAL I

ST 403 : OPTIONAL II

#### ST 404 : OPTIMIZATION TECHNIQUES-II

Kuhn-Tucker optimality conditions, Convex programming  
and duality. Unconstrained and transformation  
optimization techniques. Quadratic programming. Non-linear  
programming. Geometric Programming. Goal programming  
Elements of Dynamic Programming.

#### Books Recommended

1. Kambo, N.S. : Mathematical Programming Techniques
2. Taha, H.A. : Operations Research : An Introduction

#### ST 405 : PRACTICALS - II

Practicals are based on ST 301, ST 302, ST 303

1. Linear Estimation.
2. CRD/RBD/LSD.
3. Factorial designs and confounding.
4. Missing-plot techniques.
5. Analysis of Covariance.
6. BIBD.
7. MLE by iterative procedures.
8. Censored Samples and related estimation.
9. Control charts.
10. Process capability Index.
11. Sampling plans.

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