



**M. J. P. Rohilkhand University ,
Bareilly.**

Syllabus of

M.Sc. / M.A. Statistics

(Fourth and Fifth year of Higher education)

Under National Education Policy 2020

To be effective from 2022-23

Constructed and Approved by :

Board of Studies in Statistics , MJP Rohilkhand University, Bareilly

Dr Shubhra Katara, Bareilly College, Bareilly.

Convener

Dr. Sanjeev Panwar , ICAR, New Delhi.

Member

Dr. Anil Kumar, IASRI , PUSA , NEW Delhi.

Member

Semester wise Codes and Titles of the papers

Ist Year – Semester I					
Paper No.	Paper Code	Title of Paper	Credits	Type	Marks
Paper 1	STCT 101	Statistical Mathematics -I	4	Core	100
Paper 2	STCT 102	Measure theory and Probability	4	Core	100
Paper 3	STCT 103	Matrix Theory	4	Core	100
Paper 4	STCT 104	Sampling Theory - I	4	Core	100
Paper 5	STCP 105	Practical	4	Core	100
Paper 6	STEM 106	Minor subject - Applied Statistics	4	Elective	100
Paper 7	STRP 107	Research Project / Survey work / Agricultural Statistics Project/ Internship/ Industrial Training	-	Project	-
		Total Credits Semester I	24		
Ist Year Semester II					
Paper No.	Paper Code	Title of Paper	Credits	Type	Marks
Paper 1	STCT 201	Statistical Mathematics -II	4	Core	100
Paper 2	STCT 202	Advanced Probability Theory And Distributions	4	Core	100
Paper 3	STCT 203	Analysis of Variance and Design of Experiments	4	Core	100
Paper 4	STET 204	Econometrics	4	Elective	100
Paper 5	STCP205	Practical	4	Core	100
	STRP207	Research Project / Survey work / Internship/ Industrial Training (In continuation with Semester I)	8	Project	100
		Total Credits Semester II	28		
IInd Year - Semester III					
Paper No.	Paper Code	Title	Credits	Type	Marks
Paper 1	STCT 301	Statistical Inference - I	4	Core	100
Paper 2	STCT 302	Sampling Theory -II	4	Core	100
Paper 3	STCT 303	Operations Research	4	Core	100
Paper 4	STET 304	Demography and Population Statistics	4	Elective	100
Paper 5	STCP 305	Practical	4	Core	100
Paper 6	STRP 307	Master Dissertation (to be continued in Semester IV)	-	Dissertation	-
		Total Credits Semester III	20		

IInd Year Semester IV					
	Paper Code	Title of the Paper	Credits	Type	Marks
Paper 1	STCT 401	Statistical Inference - II	4	Core	100
Paper 2	STCT 402	Multivariate Analysis	4	Core	100
Paper 3	STET 403A or STET 403B Or STET 403 C	Engineering Statistics Or Stochastic process Or Reliability Theory & Life Distribution	4	Optional	100
Paper 4	STET 404A Or STET404B Or STET404C	Data Science using R Or Statistical Genetics Or Actuarial Statistics	4	Specialisation	100
Paper 5	STCP405	Practical	4	Core	100
Paper 6	STRP407	Master Dissertation (to be continued from Semester III)	8	Dissertation	100
		Total Credits Semester IV	28		

M.Sc. / M.A. Statistics 1st Year

Semester I

Paper I Statistical Mathematics – I (Real Analysis) (STCT 101)

Unit I Limit and Continuity, Differentiation of Functions of one variable , Successive Differentiation, Partial Differentiation, Mean Value Theorems, Taylor and Maclaurin's series.

Unit II Maxima –Minima of functions of many variables (method of undetermined multipliers only) , Jacobians.

Unit III Riemann Integration, fundamental Theorems and Mean value Theorems of Integral Calculus , Infinite Integrals with tests of Convergence.

Unit IV Differentiation and Integration under Integral signs, Change of Order of Integration , Beta and Gamma Integrals. Double and Multiple Integrals. Dirichlet's Integral, Term by term differentiability and Integrability of series.

Suggested Readings

- Bartle RG. 1976. Elements of Real Analysis. John Wiley. Chatterjee SK. 1970. Mathematical Analysis. Oxford & IBH.
- Gibson GA. 1954. Advanced Calculus. Macmillan.
- Hildebrand FB. 1956. Introduction to Numerical Analysis. Tata McGraw Hill.
- Priestley HA. 1985. Complex Analysis. Clarenton Press.
- Rudin W. 1985. Principles of Mathematical Analysis. McGraw Hill. Sauer T. 2006. Numerical Analysis With CD-Rom. Addison Wesley.
- Scarborough JB. 1976.
- Numerical Mathematical Analysis. Oxford & IBH. Stewart J. 2007. Calculus. Thompson.

Paper II : Measure Theory and Probability (STCT 102)

UNIT I	Sets, Sequences Of Sets & Their Limits, Fields, Sigma Fields, Minimal Sigma Field, Monotone Classes Of Sets, Borel Sigma Field. Set function, Continuity of Set Function,
UNIT II	Measure Function, Properties Of Measure Function, Probability Measure And Probability Space, Lebesgue Measure, Lebesgue-Stieltjes Measure And Its Properties, Caratheodory Extension, Theorem Of Measure Function (Statement Only).
Unit III	Measurable function, Random Variable As A Measurable Function, Sequences Of Measurable Function And Random Variables. Convergence of Sequence Of Random Variables, Distribution In Probability, In P-Th Mean And Almost Everywhere, Their Criteria And Inter-Relations, Helly-Bray Theorem (statement only), Borel Cantelli Lemma, Borel 0-1 Law
UNIT IV	Khintchine's Weak & Strong Law Of Large Numbers and Kolmogorov's Theorems , Central Limit Theorems: Linderberg-Levy Theorem; Laplace-Liapunoff Theorem; Linderberg-Feller Theorem (Statement Only) Characteristics Functions, Inversion Theorem.

Suggested Readings :

- Halmos, P. R. (2013). *Measure theory* (Vol. 18). Springer.
- Kubrusly, C. S. (2015). *Essentials of measure theory*. Springer International Publishing.
- Doob, J. L. (2012). *Measure theory* (Vol. 143). Springer Science & Business Media.
- Bhat, B. R. (2007). *Modern probability theory*. New Age International.
- Ash, R. B., Robert, B., Doleans-Dade, C. A., & Catherine, A. (2000). *Probability and measure theory*. Academic press.
- Loeve, M. (2017). *Probability theory*. Courier Dover Publications.

Paper III Matrix Theory (STCT 103)

UNIT I Matrix Algebra: Basic Terminology, Linear Independence And Dependence Of Vectors. Row and column spaces, Echelon form. Determinants,

Unit II Trace Of Matrices Rank And Inverse Of Matrices. Special Matrices – Idempotent, Symmetric, Orthogonal. Eigen Values And Eigen Vectors, Spectral Decomposition Of Matrices.

Unit III Unitary, Similar, Hadamard, Circulant, Helmert's matrices. Kronecker and Hadamard product of matrices, Kronecker sum of matrices. Sub-Matrices And Partitioned Matrices, Permutation Matrices

Unit IV Full Rank Factorization, Gramian Root Of A Symmetric Matrix. Solutions Of Linear Equations, Equations Having Many Solutions. Generalized Inverses, Moore-Penrose Inverse, Applications Of G-Inverse. Inverse and Generalized Inverse of Partitioned Matrices, Differentiation And Integration Of Vectors And Matrices, Quadratic Forms.

Suggested Reading

- Aschbacher M. 2000. Finite Group Theory. Cambridge University Press.
- Deo N. 1984. Graph Theory with Application to Engineering and Computer Science. Prentice Hall of India.
- Gentle JE. 2007. Matrix Algebra: Theory, Computations and Applications in Statistics. Springer.
- Graybill FE. 1961. Introduction to Matrices with Applications in Statistics. Wadsworth Publ.
- Hadley G. 1969. Linear Algebra. Addison Wesley.
- Harville DA. 1997. Matrix Algebra from a Statistician's Perspective. Springer.
- Rao CR. 1965. Linear Statistical Inference and its Applications. 2nd Ed. John Wiley.
- Robinson DJS. 1991. A Course in Linear Algebra with Applications. World Scientific.

Paper IV Sampling Theory - I STCT 104

Unit I Sample Survey Vs Complete Enumeration, Probability Sampling, Sample Space, Sampling Design, Sampling Strategy; Determination Of Sample Size; Confidence Interval;

Unit II Simple random sampling, Estimation of population proportion, Stratified random sampling, Proportional allocation and optimal allocation, Inverse sampling.

Unit III Cluster Sampling, Multi-Stage Sampling, Systematic Sampling,

Unit IV Use Of Auxiliary Information At Estimation, Ratio , Product And Regression Estimators. Double sampling. Collection of Official Statistics in India.

Suggested Readings

- Cochran WG. 1977. Sampling Techniques. John Wiley.
- Murthy MN. 1977. Sampling Theory and Methods. 2nd Ed. Statistical Publ. Soc., Calcutta. • Singh D, Singh P and Kumar P. 1982. Handbook on Sampling Methods. IASRI Publ.
- Sukhatme PV, Sukhatme BV, Sukhatme S and Asok C. 1984. Sampling Theory of Surveys with Applications. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.
- Cochran WG. 2007. Sampling Techniques, 3rd Edition. John Wiley & Sons Publication

Paper V Practical STCP 105

There will be 20 Practicals based on Paper III and Paper IV.

Paper 6 Minor Elective : Applied Statistics STEM 106

Unit I Box-Plot, Descriptive Statistics, Exploratory Data Analysis, Theory Of Probability, Random Variable And Mathematical Expectation.

Unit II Discrete And Continuous Probability Distributions, Binomial, Poisson, Negative Binomial, Normal Distribution, Beta And Gamma Distributions And Their Applications. Concept Of Sampling Distribution: Chi-Square, t And F Distributions. Tests of Significance Based On Normal, Chi-Square, t and F Distributions.

Unit III Introduction to Theory of Estimation And Confidence-Intervals, Simple And Multiple Correlation Coefficient, Partial Correlation, Rank Correlation, Simple and Multiple Linear Regression Model,

Unit IV Test of Significance of Correlation Coefficient And Regression Coefficients, Coefficient of Determination, Fitting of Quadratic Models. Introduction to ANOVA: One way and Two Way, Introduction To Sampling Techniques, Introduction To Multivariate Analysis, Transformation Of Data.

Practical •

Exploratory Data Analysis, Fitting Of Distributions, Binomial, Poisson, Negative Binomial, Normal. Large Sample Tests, Testing Of Hypothesis Based On Exact Sampling Distributions , Chi Square, t and F. Confidence Interval Estimation and Correlation And Regression Analysis, Fitting Of Linear And Quadratic Model. Non-parametric tests. ANOVA: One way, Two Way Models.

Suggested Readings

- Goon A.M, Gupta M.K and Dasgupta B. 1977. An Outline of Statistical Theory. Vol. I. The World Press.
- Goon A.M, Gupta M.K. and Dasgupta B. 1983. Fundamentals of Statistics. Vol. II. The World Press.
- Hoel P.G. 1971. Introduction to Mathematical Statistics. John Wiley.
- Hogg R.V and Craig T.T. 1978. Introduction to Mathematical Statistics. Macmillan.
- Morrison D.F. 1976. Multivariate Statistical Methods. McGraw Hill.
- Hogg RV, McKean JW, Craig AT. 2012. Introduction to Mathematical Statistics 7th Edition.
- Siegel S, Johan N & Casellan Jr. 1956. Non-parametric Tests for Behavior Sciences. John Wiley.

- Anderson TW. 2009. An Introduction to Multivariate Statistical Analysis, 3rd Ed . John Wiley

M.Sc. / M.A. Statistics Ist Year

Semester II

Paper I Statistical Mathematics – II (Complex and Numerical Analysis)
(STCT 201)

Unit I Regular Functions , It's Construction and Properties, Differentiation and Integration.

Unit II Taylor's and Laurent's Series , Theory of Residuals , Contour Integration .

Unit III Numerical Analysis , Various Interpolation methods and Formulae, Central Difference Formulae. Numerical Quadrature Formulae with remainder terms , Numerical Differentiation and Integration. Inverse Interpolation.

Unit I V Summation of Series , Elementary difference equation , Linear Equation Of first Order, Exact equation of First Order, Linear Difference Equation With Constant Coefficient.

Suggested Reading

- Bartle RG. 1976. Elements of Real Analysis. John Wiley. Chatterjee SK. 1970. Mathematical Analysis. Oxford & IBH.
- Gibson GA. 1954. Advanced Calculus. Macmillan.
- Henrice P. 1964. Elements of Numerical Analysis. John Wiley.
- Hildebrand FB. 1956. Introduction to Numerical Analysis. Tata McGraw Hill.
- Priestley HA. 1985. Complex Analysis. Clarenton Press.
- Rudin W. 1985. Principles of Mathematical Analysis. McGraw Hill. Sauer T. 2006. Numerical Analysis With CD-Rom. Addison Wesley. Scarborough JB. 1976. Numerical Mathematical Analysis. Oxford & IBH. Stewart J. 2007. Calculus.Thompson.

Paper II : Advanced Probability Theory And Distributions (STCT 202)

Unit I Descriptive Statistics, Probability Distributions, Discrete Probability Distributions , Bernoulli, Binomial, Poisson, Negative-Binomial, Geometric And

Hyper Geometric, Uniform, Multinomial , Properties Of These Distributions. Continuous Probability Distributions , Rectangular, Exponential, Cauchy, Normal, Gamma, Beta Of Two Kinds, Weibull, Lognormal, Logistic, Pareto. Properties of these distributions. Probability Distributions Of Functions Of Random Variables.

Unit II Concepts Of Compound, Truncated And Mixture Distributions (definitions and examples). Sampling Distributions Of Sample Mean And Sample Variance From Normal Population, Central And Non–Central Chi-Square, t and F Distributions, Their Properties And Inter Relationships.

Unit III Concepts Of Random Vectors, Moments And Their Distributions. Bivariate Normal Distribution - Marginal And Conditional Distributions. Distribution Of Quadratic Forms. Cochran Theorem, Correlation, Rank Correlation, Correlation Ratio And Intra-Class Correlation. Regression analysis, Partial and Multiple Correlation And Regression.

Unit IV Sampling Distribution Of Correlation Coefficient, Regression Coefficient. Categorical Data Analysis, Association Between Attributes. Order Statistics, Distribution Of nth Order Statistics, Joint Distribution Of Several Order Statistics and their Functions, Marginal Distributions Of Order Statistics.

Suggested Readings

- Arnold BC, Balakrishnan N and Nagaraja HN. 1992. A First Course in Order Statistics. JohnWiley.
- David HA and Nagaraja HN. 2003. Order Statistics. 3rd Ed. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. Modern Mathematical Statistics. John Wiley. • Huber PJ. 1981. Robust Statistics. John Wiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. Continuous Univariate Distributions. JohnWiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. Discrete Univariate Distributions. JohnWiley.
- Rohatgi VK and Saleh AK Md. E. 2005. An Introduction to Probability and Statistics. 2nd Ed. John Wiley.

- Rao CR. 1965. Linear Statistical Inference and its Applications. John Wiley.

Paper III : Analysis of Variance and Design of Experiments (STCT 203)

Unit I Analysis of variance , Basic Assumptions , One way ANOVA, Two way ANOVA .Need For Designing Of Experiments, Characteristics of a Good

Design. Basic Principles Of Designs- Randomization, Replication And Local Control.

Unit II Uniformity trials, size and shape of plots and blocks, , Completely randomized design, randomized block design and Latin square design.

Unit III Factorial Experiments , Orthogonality and Partitioning Of Degrees Of Freedom. Confounding.

Unit IV Split Plot and Strip Plot Designs, Analysis Of Covariance and Missing Plot Techniques In Randomized Block And Latin Square Designs, Transformations, Balanced Incomplete Block Design, Lattice design, Alpha Design - Concepts, Randomization Procedure, Analysis and Interpretation of Results. Response Surfaces. Combined Analysis.

Suggested Reading

- Cochran WG and Cox GM. 1957. Experimental Designs. 2nd Ed. John Wiley.
- Dean AM and Voss D. 1999. Design and Analysis of Experiments. Springer.
- Montgomery DC. 2012. Design and Analysis of Experiments, 8th Ed. John Wiley.
- Federer WT. 1985. Experimental Designs. MacMillan.
- Fisher RA. 1953. Design and Analysis of Experiments. Oliver & Boyd.
- Nigam AK and Gupta VK. 1979. Handbook on Analysis of Agricultural Experiments. IASRI Publ.
- Pearce SC. 1983. The Agricultural Field Experiment: A Statistical Examination of Theory and Practice. John Wiley.

Paper IV Elective paper Econometrics (STCT 204)

Unit I Representation of Economic phenomenon, relationship among economic variables, linear and non-linear economic models, single equation general linear regression model, basic assumptions, Ordinary least squares method of estimation for simple and multiple regression models; summary statistics

correlation matrix, co-efficient of multiple determination, standard errors of estimated parameters, tests of significance and confidence interval estimation. BLUE properties of Least Squares estimates. Chow test, test of improvement of fit through additional regressors. Maximum likelihood estimation.

Unit II Heteroscedasticity, Auto-correlation, Durbin Watson test, Multi-collinearity. Stochastic regressors, Errors in variables, Use of instrumental variables in regression analysis. Dummy Variables. Distributed Lag models: Koyck's Geometric Lag scheme, Statistical Sciences: Agricultural Statistics Adaptive Expectation and Partial Adjustment Mode, Rational Expectation Models and test for rationality.

Unit III Simultaneous equation model: Basic rationale, Consequences of simultaneous relations, Identification problem, Conditions of Identification, Indirect Least Squares, Two-stage least squares, K-class estimators, Limited Information and Full Information Maximum Likelihood Methods, three stage least squares, Generalized least squares, Recursive models, SURE Models. Mixed Estimation Methods, use of instrumental variables, pooling of cross-section and time series data, Principal Component Methods.

Unit IV Problem and Construction of index numbers and their tests; fixed and chain based index numbers; Construction of cost of living index number. Demand analysis – Demand and Supply Curves; Determination of demand curves from market data. Engel's Law and the Engel's Curves, Income distribution and method of its estimation, Pareto's Curve, Income inequality measures.

Suggested Readings

- Croxton F.E. and Cowden D.J. 1979. Applied General Statistics. Prentice Hall of India.
- James H.S. and Mark W.W. 2017. Introduction to Econometrics, 3rd Ed. John Wiley
- Johnston J. 1984. Econometric Methods. McGraw Hill.
- Judge G.C., Hill R.C., Griffiths W.E., Lutkepohl H and Lee T.C. 1988. Introduction to the Theory and Practice of Econometrics. 2nd Ed. John Wiley.

- Kmenta J. 1986. Elements of Econometrics. 2nd Ed. University of Michigan Press.
- Koop G. 2007. Introduction to Econometrics. John Wiley.
- Maddala G.S. 2001. Introduction to Econometrics. 3rd Ed. John Wiley.
- Pindyck R.S. and Rubinfeld D.L. 1998. Econometric Models and Economic Forecasts. 4th Ed. McGraw Hill.
- Verbeek M. 2008. A Guide to Modern Econometrics. 3rd Ed. John Wiley.

Paper V : Practical (STCT 205)

There will be 20 Practicals based on Paper 3 and Paper 4.

M.Sc. / M.A. Statistics

IIInd Year - Semester III

Paper 1 Statistical Inference –I STCT301

Unit I Concepts Of Point Estimation: Unbiasedness, Consistency, Efficiency And Sufficiency. Neyman’s Factorization Theorem With Applications.

Unit II MVUE, Rao Blackwell Theorem, Completeness, Lehmann- Scheffe Theorem. Fisher information, Cramer-Rao lower bound and its applications.

Unit III Moments, Minimum Chi-Square, Least Square And Maximum Likelihood Methods Of Estimation and their properties.

Unit IV Interval Estimation-Confidence Level, Shortest Length CI. CI for the Parameters Of Normal, Exponential, Binomial And Poisson Distributions.

Suggested Reading

- Box G.E.P. and Tiao G.C. 1992. Bayesian Inference in Statistical Analysis. John Wiley.
- Casela G and Berger R.L. 2001. Statistical Inference. Duxbury Thompson Learning.
- Christensen R. 1990. Log Linear Models. Springer.
- Conover W.J. 1980. Practical Nonparametric Statistics. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. Modern Mathematical Statistics. John Wiley.
- Lehmann EL. 1986. Theory of Point Estimation. John Wiley.
- Rao C.R. 2009. Linear Statistical Inference and Its Applications, 3rd Ed. John Wiley.
- Rohatgi V.K. and Saleh A.K. Md. E. 2005. An Introduction to Probability and Statistics. 2nd Ed. John Wiley.

Paper 2 Sampling Theory - II STCT302

Unit I Double sampling, Successive sampling on two occasions. Unbiased ratio type estimators .

Unit II Multistage sampling with equal probability, Separate and combined ratio estimator.

Unit III PPS Sampling with and without replacement, Cumulative method and Lahiri's method of selection, Horvitz-Thompson estimator,

Unit IV Ordered and unordered estimators, Sampling strategies due to Midzuno-Sen and Rao-Hartley-Cochran. Non-sampling errors – sources and classification, Non-response in surveys, Randomized response techniques, Response errors/ Measurement errors.

Suggested Reading

- Chaudhari A and Stenger H. 2005. Survey Sampling Theory and Methods. 2nd Ed. Chapman & Hall.
- Chaudhari A and Voss J.W.E. 1988. Unified Theory and Strategies of Survey Sampling. North Holland.
- Cochran W.G. 1977. Sampling Techniques. John Wiley. • Hedayat A.S. and Sinha B.K. 1991. Design and Inference in Finite Population Sampling. John Wiley.
- Murthy M.N. 1977. Sampling Theory and Methods. 2nd Ed. Statistical Publ. Society, Calcutta.
- Sukhatme P.V., Sukhatme B.V., Sukhatme S and Asok C. 1984. Sampling Theory of Surveys with Applications. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.

Paper 3 Linear Programming and Operations Research STCT 303

Unit I Convex Sets and their properties, Separating and Supporting Hyperplanes , Linear Programming and its Formulation, Graphical solution , Theory of Simplex Methods, Simplex Algorithm.

Unit II Duality in Linear Programming , Dual Simplex Algorithm , Revised Simplex Algorithm Method, Degeneracy , Zero Sum Two Person Games, Saddle Point , Minimax Theorem for Rectangular Games.

Unit III Assignment Problem , Reduction Theorem , Hungarian Method , Travelling Salesman Problem, Inventory control: Carrying , Shortage and Replenishing Costs, Types of Inventory Systems , Inventory Policies, Demand and Replenishment properties.

Unit IV Transportation Problem and its variations , U- V Method , Transportation Algorithm, Degeneracy in Transportation .

Unit V Replacement of Capital Equipment in anticipation of failures , Inspection of Emergency Equipment . Sequencing of n-jobs through two and three Machines , PERT and Critical Path Method.

Suggested Readings

- Gass, S.L. Linear Programming – Methods and Applications
- Shrinath Linear Programming
- Loomba , N.P. Linear Programming – An Introductory Analysis
- Mackinsey - Theory of Games
- Kanti Swaroop, P.K. Gupta and Manmohan - Operations Research

Paper 4 Demography and Population Statistics STET 304

Unit I Vital Statistics and Population Studies, Growth of Population Productions, Various Rates and Ratio and their uses, Registration method of Births and Deaths in India , Population Census In India .

Unit II Measurements of Vital Events, Birth and Fertility rates – CBR,ASFR, TFR, GRR, NRR, Population trends, Mortality and Death Rates – CDR, STDR - Direct and Indirect.

Unit III Mortality Indices , Life Tables, Construction of life Tables from Census, Force of Mortality

Unit IV Migration And Distribution of Population : Migration and demographic analysis , Definition of Migration, Internal and International migration Manpower and Working Activities : Source of Data, Types Of Economic activities and and impact on Socio Economic Structures.

Suggested Readings

- Core : Demography
- Barceley : Techniques of Population Analysis
- Kamithan and Bhende : Principles of Population Studies
- Benjamin : Elements of Vital Statistics

Paper 5 Practical STCP 305

There will be 20 practicals Based on Paper 2, 3 and 4

M.Sc. / M.A. Statistics

IIInd Year - Semester IV

Paper 1 Statistical Inference –II STCT401

Unit I Fundamentals of hypothesis testing-statistical hypothesis, statistical test, critical region, types of errors, test function, randomized and non- randomized tests, level of significance, power function, most powerful tests: Neyman-Pearson fundamental lemma, MLR families and UMP tests for one parameter exponential families.

Unit II Concepts of consistency, unbiasedness and invariance of tests. Likelihood Ratio tests, asymptotic properties of LR tests with applications (including homogeneity of means and variances). Relation between confidence interval estimation and testing of hypothesis.

Unit III Sequential Probability ratio test, Properties of SPRT. Termination property of SPRT, SPRT for Binomial, Poisson, Normal and Exponential distributions. Concepts of loss, risk and decision functions, admissible and optimal decision functions, estimation and testing viewed as decision problems, conjugate families, Bayes and Minimax decision functions with applications to estimation with quadratic loss.

Unit V Non-parametric tests: Sign test, Wilcoxon signed rank test, Runs test for randomness, Kolmogorov – Smirnov test for goodness of fit, Median test and Wilcoxon-Mann-Whitney U-test. Chi-square test for goodness of fit and test for independence of attributes. Spearman's rank correlation and Kendall's Tau tests for independence.

Suggested Reading

- Lehmann EL. 1986. Testing Statistical Hypotheses. John Wiley.
- Lehmann EL. 1986. Theory of Point Estimation. John Wiley.
- Gibbons J.D. 1985. Non Parametric Statistical Inference. 2nd Ed. Marcel Dekker.
- Kiefer J.C. 1987. Introduction to Statistical Inference. Springer.
- Randles R.H and Wolfe D.S. 1979. Introduction to the Theory of Nonparametric Statistics. John Wiley.
- Rao C.R. 2009. Linear Statistical Inference and Its Applications, 3rd Ed. John Wiley.
- Rohatgi V.K. and Saleh A.K. Md. E. 2005. An Introduction to Probability and Statistics. 2nd Ed. John Wiley.

Paper 2 Multivariate Analysis STCT402

Unit I Concept of random vector, its expectation and Variance-Covariance matrix. Marginal and joint distributions. Conditional distributions and Independence of random vectors. Multinomial distribution. Multivariate Normal distribution, marginal and conditional distributions. Sample mean vector and its distribution. Maximum likelihood estimates of mean vector and dispersion matrix. Tests of hypothesis about mean vector.

Unit II Wishart distribution and its simple properties. Hotelling's T^2 and Mahalanobis D^2 statistics. Null distribution of Hotelling's T^2 . Rao's U statistics and its distribution. Wilks' O criterion and its properties. Concepts of discriminant analysis, computation of linear discriminant function, classification

between k (t_2) multivariate normal populations based on LDF and Mahalanobis D^2 .

Unit III Principal Component Analysis, factor analysis. Canonical variables and canonical correlations. Cluster analysis: similarities and dissimilarities of qualitative and quantitative characteristics, Hierarchical clustering. Single, Complete and Average linkage methods. K-means cluster analysis.

Unit IV Path analysis and computation of path coefficients, introduction to multidimensional scaling, some theoretical results, similarities, metric and non-metric scaling methods.

Suggested Reading

- Anderson TW. 1984. An Introduction to Multivariate Statistical Analysis. 2nd Ed. John Wiley.
- Arnold SF. 1981. The Theory of Linear Models and Multivariate Analysis. John Wiley.
- Giri NC. 1977. Multivariate Statistical Inference. Academic Press.
- Johnson RA and Wichern DW. 1988. Applied Multivariate Statistical Analysis. Prentice Hall.
- Kshirsagar AM. 1972. Multivariate Analysis. Marcel Dekker.
- Muirhead RJ. 1982. Aspects of Multivariate Statistical Theory. John Wiley.
- Muirhead, RJ. (2005) Aspects of Multivariate Statistical Theory. 2nd Ed. John Wiley.
- Rao CR. 1973. Linear Statistical Inference and its Applications. 2nd Ed. John Wiley.
- Rencher AC. 2012. Methods of Multivariate Analysis. 3rd Ed. John Wiley.
- Srivastava MS and Khatri CG. 1979. An Introduction to Multivariate Statistics. North Holland.

Paper 3 Optional Paper A Engineering Statistics STCT403A

Unit I Quality of Product , Need For Quality Control, Process And Product Control, General Theory of Control Charts,

Unit II Different Types Of Control Charts For Variables And Attributes : Mean , Range, s , p , np and c charts, OC and ARL of control charts, Cumulative Sum Charts.

UNIT III Acceptance sampling plans, Single, double, multiple and sequential sampling plans for attributes, OC, ASN, AOQ and ATI curves, concepts of Producer's and Consumer's risks, AQL, LTPD and AOQL,

UNIT IV Sampling plans for inspection by variables, Use of Dodge-Roming tables.

Suggested Readings

- D.C. Montgomery. (2009): Introduction to Statistical Quality Control. Wiley. Wetherill,
- G.B. Brown, D.W.(1991): Statistical Process Control Theory and Practice, Chapman & Hall.
- Ott, E. R.(1977): Process Quality Control (McGraw Hill)
- Wetherill, G.B.(1977): Sampling Inspection and Quality control, Halsted Press. Duncan A.J.(1974): Quality Control and Industrial Statistics, IV Edition, Taraporewala and Sons.

Paper 3 Optional Paper B Stochastic Process STCT403B

UNIT I	Stochastic process: its introduction, classification, discrete/continuous spaces, types of stochastic processes with elementary problems
UNIT II	Markov chains: definition & examples, Kolmogorov's equations, Calculation of n-step transition probability matrix & its limit, stationary distribution, classification of states, transient Markov chain
UNIT III	Random walk and Gambler's ruin problem, Ideas of branching process, Poisson process,
UNIT IV	Pure birth process, pure death process, Birth & death processes: applications from social, physical and biological sciences

Suggested Readings

- Parzen, E. (1999). *Stochastic processes*. Society for Industrial and Applied Mathematics.
- Medhi, J. (1994). *Stochastic processes*. New Age International.
- Hoel, P. G., Port, S. C., & Stone, C. J. (1986). *Introduction to stochastic processes*. Waveland Press.
- Karr, A. F. (1984). Stochastic processes (Sheldon M. Ross). *SIAM Review*, 26(3), 448.
- Bhat, B. R. (2004). *Stochastic models: analysis and applications*. New Age International. Basu A.K. (2003). *Introduction to Stochastic Processes*, Narosa Publishing House.
- Feller, W. (1968): *Introduction to Probability and its Applications*, Vol.1, Wiley Eastern.
- Medhi, J, (1982): *Stochastic Processes*, Wiley Eastern.
- Suddhendu Biswas (1995). *Applied Stochastic Processes: A Biostatistical and Population oriented Approach*, Wiley Eastern.
- Bhat B.R. (2008) *Stochastic Models: Analysis and Applications*, New Age Publishers

Paper 3 Optional Paper C Reliability Theory & Life Distribution STCT403C

- UNIT I** Basic concepts of reliability and measures, components and systems, failure rate and reliability functions, reliability of series and parallel systems and other simple configurations
- UNIT II** Coherent systems, Reliability of coherent systems, hazard rate concepts, Failure models: exponential, Weibull, normal, lognormal.

UNIT III	Common life distributions and their properties-exponential, weibull Weibull, Gamma, log normal, renewal density and renewal function,
UNIT IV	Estimation of parameters of these distribution & estimation of reliability. Idea of two type censored sampling, Problems in life testing, censored and truncated experiments for exponential models.
Suggested Readings	Crowder, M. J., Kimber, A. C., Smith, R. L., & Sweeting, T. J. (2017). <i>Statistical analysis of reliability data</i> . Routledge.

Paper 4 Optional Paper A Data Science Using R STCT404A

UNIT I	Introduction to the statistical software; Basic File operations: Data objects in R, Creating vectors, Creating matrices
UNIT II	Manipulating data, Accessing elements of a vector or matrix, lists, Manipulating vectors, matrices, lists, importing of files, data frame, and computations of descriptive statistics measures
UNIT III	Boolean operators. Looping: For loop, repeat loop, while loop, if command, if else command.
UNIT IV	R-Graphics- Histogram, Box-plot, Stem and leaf plot, Scatter plot, Descriptive Statistics- frequency table, Plotting of probability distributions and sampling distributions
Suggested Readings	Wickham, H. (2008). A First Course in Statistical Programming with R. <i>Journal of Statistical Software</i> , 28, 1-3. Purohit S.G., Gore,S.D. and Deshmukh,S.R.(2008) Statistics Using R, Alpha Science 1. Alain F. Zuur, Elena N. Ieno, and Erik Meesters, “A Beginner’s Guide to R”, Springer, 2009, ISBN:978-0-387-93836-3.

2. W Michael J. Crawley, "Statistics: An Introduction using R", Wiley, 2005, ISBN 0-470-02297-3.
3. Phil Spector, "Data Manipulation with R", Springer, New York, 2008, ISBN 978-0-387-74730-9.
4. Maria L. Rizzo, "Statistical computing with R", Chapman & Hall/CRC, Boca Raton, FL, 2008, ISBN 1-584-88545-9.
5. W. John Braun and Duncan J. Murdoch, "A first course in Statistical programming with R", Cambridge University Press, Cambridge, 2007, ISBN 978-0521872652.

Paper 4 Optional Paper B Statistical Genetics STCT404B

Unit I Physical basis of inheritance. Analysis of segregation, detection and estimation of linkage for qualitative characters. Amount of information about linkage, combined estimation, disturbed segregation.

Unit II Gene and genotypic frequencies, Random mating and Hardy -Weinberg law, Application and extension of the equilibrium law, Fisher's fundamental theorem of natural selection. Disequilibrium due to linkage for two pairs of genes, sex-linked genes, Theory of path coefficients.

Unit III Concepts of inbreeding, Regular system of inbreeding. Forces affecting gene frequency - selection, mutation and migration, equilibrium between forces in large populations, Random genetic drift, Effect of finite populationsize.

Unit IV Polygenic system for quantitative characters, concepts of breeding value and dominance deviation. Genetic variance and its partitioning, Effect of inbreeding on quantitative characters, Multipleallelism in continuous variation, Sex-linked genes, Maternal effects - estimation of their contribution.

Suggested Reading

- Agarwal BL and Agarwal SP. 2007. Statistical Analysis of Quantitative Genetics. New Age International Publisher.
- Bailey NTJ. 1961. The Mathematical Theory of Genetic Linkage. Clarendon Press.
- Balding DJ, Bishop M and Cannings C. 2001. Hand Book of Statistical Genetics. John Wiley.
- Crow JF and Kimura M. 1970. An Introduction of Population Genetics Theory. Harper and Row.
- Dahlberg G. 1948. Mathematical Methods for Population Genetics. Inter Science Publ.
- East EM and Jones DF. 1919. Inbreeding and Outbreeding.
- Lippincott JB & Co. Ewens WJ. 1979. Mathematics of Population Genetics. Springer. Restructured and Revised Syllabi of Post-graduate Programmes Vol. 2
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- Falconer DS. 1985. Introduction to Quantitative Genetics. ELBL
- Fisher RA. 1949. The Theory of Inbreeding. Oliver & Boyd.
- Fisher RA. 1950. Statistical Methods for Research Workers. Oliver & Boyd.
- Fisher RA. 1958. The Genetical Theory of Natural Selection. Dover Publ.
- Kempthorne O. 1957. An Introduction to Genetic Statistics. The Iowa State Univ. Press.

Paper 4 Optional Paper C Actuarial Statistics STCT404B

UNIT I Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions. Insurance applications, sum of random variables. Utility theory: Utility functions, expected utility criterion, types of utility function, insurance and utility theory, models for individual claims and their sums.

UNIT II Survival function, Uncertainty of age at death, time until-death for a person, curate future lifetime, force of mortality. Life table and its relation with survival function, life table characteristics, assumptions for fractional ages, some analytical laws of mortality, select and ultimate life table

UNIT III Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding. Principles of Premium Calculation: Properties of premium principles, examples of premium principles. Individual risk models: models for individual claims, the sum of independent claims, approximations and their applications.

UNIT IV Life insurance: Insurance payable at the moment of death and at the end of the year of death level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance, recursions, commutation functions. Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions,

varying annuities, recursions, complete annuities. Net single premiums, Factor affecting mortality and selections.

Suggested Readings

- Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J. (1997). Actuarial Mathematics. Society of Actuaries, Itasca, Illinois, U.S.A. Daykin,
- C. D., Pentikainen, T. and Pesonen, M. (1993). Practical Risk Theory for Actuaries. Chapman & Hall/CRC.
- Deshmukh, S.R. (2009). Actuarial Statistics: An Introduction Using R, University Press, India. Dickson, C. M. D. (2005). Insurance Risk and Ruin (International Series no.1 Actuarial Science), Cambridge University Press.
- Klugman, S. A., Panjer, H. H., and Willmotand, G. E. (2019). Loss Models: From Data to Decisions. Willy publication.
- Neill, A. (1977). Life Contingencies, Heinemann. Rotar, V.I. (2015). Actuarial Models: The Mathematics of Insurance, 2nd ed., CRC Press, New York.
- Spurgeon, E.T. (1972). Life Contingencies, Cambridge University Press.

Paper 5 Practical STCP405

There will be 15 Practicals Based on paper 3, 4 and 5

Evaluation and Assessment Method

1. Continuous Internal Evaluation : 25 marks

There will be continuous internal evaluation of student and they will be awarded marks in each paper by concerned Professor / Teacher out of 25 marks .

Suggested continuous evaluation method :

- I) Test / Quiz / Assignment / Seminar - 20 marks
- II) Class attendance / Interaction - 05 Marks

2. End Semester Examinations : 75 Marks

There will be end – semester exam for each paper as per the following pattern :

Suggested Question Paper Pattern for end – semester examination

Time : 3 hours

M/M 75

Note : Attempt any five questions . All questions carry equal (= 15) marks.
(Questions may have two or more than two parts .)

Q. 1. (From Unit I)

Q. 2. (From Unit I)

Q. 3. (From Unit II)

Q. 4. (From Unit II)

Q. 5. (From Unit III)

Q. 6. (From Unit III)

Q. 7. (From Unit IV)

Q. 8. (From Unit IV)

