MAHARSHI DAYANAND UNIVERSITY, ROHTAK
DEPARTMENT OF STATISTICS

Scheme of the examination for M.Sc. (Statistics) w.e.f. 2020-21 (under CBCS)

The duration of the course of instruction for M.Sc. (Statistics) programme shall be of two years (Four Semesters).There will be Five Theory Papers and Two Practicals in each semester. In addition of theory and practicals, students will have to submit a project work report in M.Sc. second year. The detailed scheme of examinations for M.Sc. (Statistics) programme is as follows:-

Program Outcomes

PO1 : Recognize and think critically towards the subject Statistics curricula with sound knowledge and theoretical skills by questioning and plausible explanations.

PO2 : Nurturing the curious minds towards translation and application of statistical knowledge to find solution to real-world problems

PO3 : Prepareing the next generation statistician ready for scientific decision-making, aided with advanced statistical software translating into sharp and extensive analytics, pertinent to various domains

PO4 : Support critical thinking for data driven solution with advanced methodologies and applicable statistical software packages like SAS, R, SPSS, MINI TAB, STATA etc for scientific decision-making

PO5 : Career opportunities in public and private sectors such as Government, Insurance, Banking, Finance, Automobile, Information Technology, Pharma and many other sectors that will entail market research, forecasting and predictive analysis

Program Specific Outcomes

PSO1 : Acquired sound knowledge in theoretical and practical aspects of Statistics

PSO2 : Achieved skills to handle the real life problems through practicals and project work using suitable Statistical tools and software such as SPSS, MINI TAB and R

PSO3 : Developed confidence to acquire new statistical knowledge and expertise for a better career in statistics and also to compete in civil services, Indian statistical services and other allied services

PSO4 : Acquired the ability to formulate suitable statistical models and their fitting to real life data

PSO5 : Enhanced skills to carry out innovative research in the subjects Statistics, Mathematics and Operations Research

M.Sc. First year

Semester I

Course Code	Title of Paper	Theory Marks	Internal Assessment Marks	Maximum Marks	Hours /Week	Credits
20STA21C1	Measure Theory & Linear Algebra	80	20	100	4 hrs.	04
20STA21C2	Probability Theory	80	20	100	4 hrs.	04
20STA21C3	Statistical Methods	80	20	100	4 hrs.	04
20STA21C4	Computing Techniques	80	20	100	4 hrs.	04
20STA21C5	Applied Statistics-I	80	20	100	4 hrs.	04
20STA21CL1	Practical (Based on 20STA21C3)	50	—	50	2 hrs.	02
20STA21CL2	Practical (Based on 20STA21C4 & 20STA21C5)	50	—	50	2 hrs.	02

Semester II

Course Code	Title of Paper	Theory Marks	Internal Assessment Marks	Maximum Marks	Hours /Week	Credits
20STA22C1	Real and Complex Analysis	80	20	100	4 hrs.	04
20STA22C2	Inference-I	80	20	100	4 hrs.	04
20STA22C3	Computer Programming using C++	80	20	100	4 hrs.	04
20STA22C4	Sampling Techniques	80	20	100	4 hrs.	04
20STA22C5	Applied Statistics-II	80	20	100	4 hrs.	04
20STA22C6	Practical (Based on 20STA22C2 & 20STA22C3)	50	—	50	2 hrs	02
20STA22C7	Practical (Based on 20STA22C4 & 20STA22C5)	50	—	50	2 hrs	02
Foundation Elective To be chosen from the pool of foundation electives provided by the University.						02
Open Elective To be chosen from the pool of open electives provided by the University.						03

M.Sc Second year

Semester III

Course Code	Title of Paper	Theory Marks	Internal Assessment Marks	Maximum Marks	Hours /Week	Credits
21STA23C1	Multivariate Analysis	80	20	100	4 hrs.	04
21STA23C2	Designs of Experiments	80	20	100	4 hrs.	04
21STA23C3	Optimizations Techniques-I	80	20	100	4 hrs.	04
21STA23C4: Practical (Based on 21STA23C1)		50	—	50	2 hrs.	02
21STA23C5: Practical (Based on 21STA23C2)		50	---	50	2 hrs.	02
Any two of the following:						
21STA23D1: Stochastic Processes		80	20	100	4 hrs.	04
21STA23D2: Agricultural Statistics		80	20	100	4 hrs.	04
21STA23D3: Methods of Operation Research		80	20	100	4 hrs.	04
21STA23D4: Statistical Programming Using R Langauge		80	20	100	4 hrs.	04
Open Elective To be chosen from the pool of open electives provided by the University.						03

Semester IV

Course Code	Title of Paper	Theory Marks	Internal Assessment Marks	Maximum Marks	Hours /Week	Credits
21STA24C1	Econometrics	80	20	100	4 hrs.	04
21STA24C2	Inference-II	80	20	100	4 hrs.	04
21STA24C3	Optimization Techniques-II	80	20	100	4 hrs.	04
21STA24CL3: Practical (Based on 21STA24C3)		50	—	50	2 hrs.	02
21STA24CL4: Practical (Based on 21STA24C1 & 21STA24C2)		50	-----	50	2 hrs.	02
21STA24C6: **Project Work**		-	-	100 **(Evaluation: 75 and Viva Voce : 25 marks)**	4 hrs.	04
Any two of the following:						
21STA24D1: Queuing Theory		80	20	100	4 hrs.	04
21STA24D2: Actuarial Statistics		80	20	100	4 hrs.	04
21STA24D3: Clinical Trials		80	20	100	4 hrs.	04
21STA24D4: Official Statistics		80	20	100	4 hrs.	04

Project work:

The project work will start in the beginning of 'M.Sc. (Second year)' under the approved supervisors from amongst faculty members of the department. The last date for the submission of project work will be one month after the theory papers of 4th semester. The evaluation of the Project Work and conduct of the viva-voce will be done by a single external examiner after 4th semester or the date prescribed by the University from time to time.

HOD (STATISTICS)

M. Sc. Semester-I
20STA21C1 (Measure Theory and Linear Algebra)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching hours: 04 hrs per week.

Paper Code: 20STA21C1
Paper: Measure Theory and Linear Algebra
Course Objectives

1 To Understand the Applications of Measure Theory in Probability Theory
2 To Acqire Knowledge about the Geometrical Aspects of Linear Algebra
3 To Understand Concepts of Matrices, Matrix Algebra and Vector Spaces
4 To Acquint with the Idea of Linear Transformations
5 To Achieve Skills for Computing Eigen Values and Eigen Vectors

Course Outcomes

1 Acquired Knowedge about the Fundamentals of Probability Theory
2 Able to Understand Applications of Measure Theory in Inferential Statistics
3 Acquinted with the Concept of Lebesgue Integal
4 Achieved Skills for Computing Eigen Values and Eigen Vectors
5 Obtained Understanding about the Significance of Vector Spaces in Statistics

Unit–I

Field and Sigma Field. Measure and Probability Measure. Outer Measurability of Sets. Class of Measurable Sets. Construction of Outer Measure using Sequential Concerning Classes. Lebesgue Measure. Construction of Non-Measurable Sets.

Unit–II

Measurable Function as a Random Variable. Simple Functions. Sequences and Algebra of Measurable Functions. Approximation Theorem of Measurable Functions. Concepts of Almost Everywhere (a.e) and Almost Uniform Convergence. Egoroffs Theorem. Lusin Theorem.

Unit–III

Convergence in Measure. Fundamental in Measure. F.Riesz Theorem for Convergence in Measure. Integral of a Measurable Function w.r.t a Measure. Bounded Convergence Theorem. Fatou's Lemma, Monotone Convergence Theorem. General Lebesgue Integral and Lebesgue Dominated Convergence Theorem.

Unit–IV

Linear and Orthogonal Transformation of a Matrix. Eigen Values and Eigen Vectors of a Liner Transformation. Quadratic Forms and Their Reduction to Canonical Form. Signature of a Matrix. Positive Definite Matrix.

Books Suggested:-

1. Rana, I.K. (2007). An Introduction to Measure and Integration. Narosa Publication.
2. Jain, P.K, Gupta, V.P., & Jain, P. (2019). Lebesgue Measure and Integration. New Age International Publishers.
3. Halmos, P.R. (2008). Measure Theory. Springer.
4. Royden, H.L., & Fitzpatrick, P. (2017). Real Analysis. Pearson.
5. Datta, K.B. (2004). Matrix and Linear Algebra. Prentice-Hall of India Pvt.Ltd.
6. Lay, D.C. (2002). Linear Algebra and its Applications. Pearson.
7. Hoffman, K., & Kunze, R. (2015). Linear Algebra. Pearson.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

20STA21C2 (Probability Theory)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching hours: 04 hrs per week.

Paper Code: 20STA21C2
Paper: Probability Theory
Course Objectives

1 To understand Theoretical Concepts of Probabilities
2 To Know about the Random Varaibles and Related Probability Functions
3 To Acquire Knowledge about the Idea of Expectation
4 To Study Different Generating Functions and Related Inequalities
5 To Study Law of Large Numbers and Central Limit Theorems

Course Outcomes

1 Developed Ability to Critical Thinkking about the Meaning of Chance.
2 Acquired Knowledge to apply the concept of Probability in Real Life
3 Ability to Identify an Approriate Probability Distribution for a Given Discrete or Continuous Random Variable
4 Acquainted with Different Generating Functions and their Important Properties
5 Understood the Methodology to Apply Results from Law of Large Numbers and the Cenral Limit Theorem

Unit–I

Random Experiment, Sample Space, Events – Simple, Composite, Mutually Exclusive and Exhaustive Events, Various Definitions of Probability, Properties of probability function, Addition Theorem, Boole's and Bonferroni's Inequalities, Conditional Probability, Multiplication Theorem, Baye's Theorem, Independence of Events.

Unit–II

Random Variables and Distribution Functions , Probability Mass function, Probability density Function, Two Dimensional Random Variables- Joint , Marginal and Conditional Distributions, Independence of Random Variables. Moments of Random Variables – Expectation, Variance, Covariance, Conditional and Marginal Expectation.

Unit–III

Probability and Moment Generating Function and their Properties, Characteristic Function and its properties, Continuity Theorem Inversion Theorem , Uniqueness Theorem of Characteristic Function, Moment Inequalities of Hölder, Minkowski, Jensen's , Cauchy- Schwartz and Lyapunov's

Unit–IV

Modes of Convergence -Convergence in Probability, almost surely, in the r^{th} mean and in distribution, their relationship. Probability Inequalities of Chebychev and Markov , Weak Law of large numbers- Chebychev's, Bernoulli's and Khintchine's Weak Law of Large Numbers, necessary and sufficient conditions for the WLLN,
Borel Cantelli Lemma, Kolmogorov inequality, Strong law of large numbers-Kolmogorov's theorem.
Central Limit Theorem, Lindeberg - Levy and Demoivre- Laplace forms of CLT.

Books Suggested:-

1. Meyer, P.L. (2017).Introductory Probability and Statistical Applications. Oxford & IBH Publishing.
2. Goon, A.M., Gupta, M.K., & Gupta B.D. (2013). Outline of Statistical Theory Vol. II. World Press.
3. Miller, I., & Miller, M. (2013). John E. Fruend's Mathematical Statistics with application. Pearson (India).
4. Mukhopadhayaya, P. (2016). Mathematical Statistics. Books and Allied.
5. Rohatgi, V. K., & Saleh, A.K. Md. E. (2008). An Introduction to Probability and Statistics. Wiley.
6. Feller, W. (1968). An Introduction to Probability Theory and its Applications. John Wiley & Sons.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

20STA21C3 (Statistical Methods)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching hours: 04 hrs per week.

Paper Code: 20STA21C3
Paper: Statistical Methods
Course Objectives

1 To understand the fundamental concepts of Statistics
2 To understand statistical techniques to analyze and interpret the categorical data
3 To analyse the data for Correlation and Regression
4 To understand the different Discrete and Continuous Distributions
5 To understand the tests for large and small samples using Fisher's Z Transformation, t-test, Chi-square & F-Statistics

Course Outcomes

1 Able to understand the Association between the Attributes.
2 Employ the principles of Linear Regression and Correlation, including Least Squares Method, predicting a particular value of Y for a given value of X and the significance of a Correlation Coefficient
3 Achieved Knowledge in applying Probability Distributions in real life problems.
4 Ability to perform test of hypothesis about mean, variance and goodness of fit.
5 Ability to perform test of hypothesis for large samples and small samples.

Unit–I

Raw and Central Moments, Skewness and Kurtosis. Analysis and Consistency of Categorical Data, Independence and Association of Attributes. Principle of Least Squares, Fitting of Curves, Correlation and Regression,

Unit–II

Correlation Ratio. Interclass Correlation. Partial and Multiple Correlations. Probability Discrete Distributions: Binomial, Poisson, Multinomial, Hyper Geometric, Geometric. Negative Binomial, Uniform

Unit–III

Probability Continuous Distributions: Rectangular, Exponential, Normal, Beta, Gamma, Weigbul, Laplace, Cauchy, Lognormal Distributions, Bivariate Normal. Sampling Distribution of Mean And Variance.

Unit–IV

Large Sample Theory, Chi-Square, Student's and Snedecor's F, Fisher's-Z Distribution and Their Applications. Elementary Ideas Of Non-Central Distributions.

Books suggested:-

1. Hogg, R.V., Mckean, J.W., & Craig A.T. (2012). Introduction to Mathematical Statistics. Pearson.
2. Goon, A.M., Gupta, M.K., & Gupta B.D. (2013). Outline of Statistical Theory Vol. I. World Press.
3. Mukhopadhayaya, P. (2016). Mathematical Statistics. Books and Allied.
4. Mood, A.M., Graybill, F.A., & Boes, D.C. (2001).Introduction to the Theory of Statistics. Mc Graw Hill.
5. Gupta, S.C., & Kapoor, V.K. (2014). Fundamentals of Mathematical Statistics. Sultan Chand & Sons, New Delhi.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

20STA21C4 (Computing Techniques)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching hours: 04 hrs per week.

Paper Code: 20STA21C4
Paper: Computing Techniques
Course Objectives

1 To learn the Laplace Transform technique to find the solution of ordinary and partial differential equations
2 To gain the knowledge of basic programming structures
3 To understand the concepts of decision making statements, arrays and functions
4 To acquire the knowledge of storage classes used in C language
5 To know the file operations and the errors during these operations

Course Outcomes

1 Ability to solve the ordinary differential equations and partial differential equations by Laplace transform and inverse Laplace transformation
2 Acquainted with the basic of C Language
3 Gained knowledge of arrays, functions and pointers to develop the programs
4 Ability to resolve the error during file operation
5 Fully equipped with the techniques of developing his own programs for Mathematical as well as Statistical Methods

Unit-I

Laplace and Inverse Laplace Transforms: Definitions and Basic Properties. Convolution Theorem. Applications of Laplace Transforms to the Solution of Linear Ordinary Differential Equations, Partial Differential Equations and Integral Equations.

Unit–II

History and features of C language, Components of C Language Data type: Basic data type, Enumerated data types, Derived date types, variable declaration: Local, Global, Parametric variables, Assignment of variables. Numeric character, real and string constants. Operators, type modifiers and expressions. Basic input/output.

Unit-III

Control statements, decision making statements, one dimensional, two dimensional and multidimensional arrays. Functions, classification of functions definition and declaration, assessing a function, Return statement. Storage classes. Parameter passing in functions recursion in functions,

Unit-IV

Pointers; Pointer and array, Pointer and functions: Pointers to Pointers, Pointers to functions, function returning pointers, functions with variable number of arguments Preprocessor, structure and union. Opening and Closing a File Pointers and their Manipulations. Error Handling during File Operations

Books Suggested:-

1. Spiegel, M.R. (1965). Schaum's Outline of Laplace transform. McGraw-Hill Education
2. Willaims, J. (1973). Laplace Transforms, Allen & Unwin Ltd.
3. Schiff, J. L. (1999). The Laplace Transform Theory and Applications. Springer.
4. N.W. McLachlan (2014). Laplace Transforms and Their Applications to Differential Equations. Dover Publications.
5. Balagurusamy, E. (2017). Programming in ANSI C. McGraw Hill Education India Private Limited.
6. Kanetkar, Y. (2017). Let Us C. BPB.
7. Schildt, H. (2017). C: The Complete Reference. McGraw Hill Education.
8. Salaria, R.S. (2017).Computer Concepts and Programming in C. Khanna Book Publishing.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and

IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

20STA21C5 (Applied Statistics-I)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching hours: 04 hrs per week

Paper Code: 20STA21C5
Paper: Applied Statistical-I
Course Objectives

1 To aware about the sources of demographic data and study the various measures of birth rate, mortality rate, reproduction rate
2 To provide training for the description and construction of complete and abridged life tables and the methods for population estimation and projection
3 To study demand analysis
4 To study various types of index numbers and their interpretation
5 To familiarize with official statistical system of India

Course Outcomes

1 Familarized with the sources of vital statistics data and how birth rate, mortality rate and reproduction rate are calculated and interpreted
2 Able to understand the population estimation and projection
3 Acquainted with complete and abridged life tables, related information and the method to construct these tables
4 Familarized with the present statistical systems of India
5 Got information about the working and publications of NSSO and CSO

Unit–I

Methods of Obtaining Demographic Data, Measurement of Population at Given Time, Rates and Ratios, Measurement of Mortality; Crude Death Rate, Specific Death Rate, Standardized Death Rate, Infant Mortality Rate. Construction of A Complete Life Table and Its Uses. Abridged Life Tables; Kings Method. Reed And Merrill's Method. Greville's Method, Chiang's Method.

Unit–II

Measurement of Fertility: Crude Birthrate, General Fertility Rate, Age Specific Fertility Rate, Total Fertility Rate, Relation Between TFR And CBR, Gross Reproduction Rate and Net Reproduction Rate, Replacement Index. Standardized Fertility Rate. Structure of Population, Stable and Quasi Stable Populations, Intrinsic Rate Of Growth, Population Projection By Component Method, Reduction of Mortality Curves; Gompertz's and Makeham Formula, Logistic Curve and Its Use In Population Projection.

Unit–III

Demand Analysis– Laws of Demand and Supply, Price and Supply Elasticity of Demand. Partial and Cross Elasticity of Demand. Income Elasticity of Demand. Utility Function Methods of Determining Demand and Supply Curves From Family Budget and Time Series Date, Leontief's Method, Pigou's Method Engel Curve And Its Different Forms,. Pareto's Law of Income Distribution. Curves of Concentration.

Unit–IV

Index Numbers and Their Construction, Uses of Index Numbers. Price, Quantity and Value Relatives, Link and Chain Relatives, Laspeyer's, Paashce's, Marshall –Edge Worth and Fisher's Index Numbers, Chain Base Index Numbers, Tests For Index Numbers. Base Shifting, Splicing and Deflating of Index Numbers. Cost of Living Index Numbers. Official Statistics: Statistics System In India CSO and NSSO And Its Function, Present Structure of The Indian Statistical System, Function of A Statistical System, Agricultural Statistics, Trade Statistics, Labour And Employment Statistics, Transport and Communication Statistics, Financial and Banking Statistics.

Books suggested:-

1. Goon, A.M., Gupta, M.K., & Gupta B.D. (2016). Fundamentals of Statistics, Vol-II. World Press.
2. Gupta, S.C., & Kapoor, V.K. (2014). Fundamental of Applied Statistics. Sultan Chand and Sons, New Delhi.
3. Mukhopadhyay, P. (2018). Applied Statistics. Books and Allied (P) Ltd.
4. Croxton, F.E., & Cowden, D.J. (1942). Applied General Statistics. Prentice-Hall, Inc.
5. Saluja, M.R. (2017). Measuring India: The Nation's Statistical System, OUP India.
6. Biswas, S., & Sriwastav G.L. (2014). Stochastic Processes in Demography and Applications. New Central Book Agency.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

20STA21CL1-Practicals (Based on **20STA21C3)** and will be of duration 3 hours.

Paper Code: 20STA21CL1
Paper: Practical's (Statistical Methods-20STA21C3)

Course Objectives

1 To understand how to analyze the categorical data for the association of attributes
2 To analyze the data for Correlation, Regression
3 To fit the distributions to the given data such as Binomial, Poisson and Negative Binomial Normal, Exponential etc.
4 To test the hypothesis for mean for single sample, two independent sample and related samples. To test the hypothesis for goodness of fit
5 To test the hypothesis for comparison of variances and to test for large samples

Course Outcomes

1 Become familiar to calculate the categorical data for the Association between the Attributes.
2 Employ the principles of Least Square for fitting Linear Regression Equation and two calculate Correlations for quantative and qualitative data
3 Achieved Knowledge in fitting Probability Distributions to the given data
4 Ability to perform test of hypothesis about mean and goodness of fit.
5 Ability to perform test of hypothesis for variances of the given population and comparision of variances for two populations. Learnt to test for large samples

20STA21CL2-Practicals (Based on **20STA21C4 & 20STA21C5)** and will be of duration 3 hours.

Paper Code: 20STA21CL2
Paper: Practical's (Computing Techniques & Applied Statistics I - 20STA21C4 & 20STA21C5)

Course Objectives

1 To understand how to analyze demographic data and how birth rate, mortality rate are calculated and interpreted
2 To understand how the economic data be analyzed
3 To make the error free C programs for solving some mathematical and statistical problem
4 To understand how complete and abridged life tables are constructed
5 To understand how to fit demand and supply curves from time series and family budget data

Course Outcomes

1 Ability to make and run error free C programs related to mathematical and statistical problems
2 Ability to analyze the demographic data, economic data etc
3 Ability to construct and analyze complete life tables and abridged life talbes
4 Ability to analyze economic data
5 Ability to fit demand and supply curve from time series and family budget data

The practical question paper will consist of five questions and the students will be required to attempt any three questions. The question paper will set on the spot jointly by the Internal and External Examiners.

Distribution of Marks will be as follows: -

Marks for Question Paper	:	36
Marks for Practical Record book	:	06
Marks for Viva-Voice	:	08
Total	:	50

M. Sc. Semester-II
20STA22C1 (Real and Complex Analysis)

Maximum Marks: 80
Internal Assessment Marks: 20
Time: 3 Hours
Teaching Hours: 4 Hours per week

Paper Code: 20STA22C1
Paper: Real and Complex Analysis
Course Objectives

1 To Understand Topology of Real Numbers
2 To acquire knowledge about the convergence and Diversions of Sequences and Functions
3 To understand the analytic properties of the complex functions
4 To acquire the knowledge about the applications of complex analysis in Statistics
5 To Gain Knowledge about Similarities of Complex Functions

Course Outcomes

1 Updated knowledge about convergence properties of complex and real functions
2 Acquired ability to learn differentiation techniques for complex functions
3 Able to understand applications of complex analysis in Bayesian inference
4 Able to understand the analytic properties of the complex functions
5 Achived Ability to Determine Integal of Complex Variables Functions

Unit–I

Topology of Real Numbers: Open Set, Closed Set, Limit Point of a Set, Bounds of a Set. Convergence and Divergence of Sequences. Cauchy's Theorem on Limits, Sequence and Series of Functions and Their Convergence Properties.

Unit–II

Functions of a Complex Variable and Their Analytic Properties. Cauchy's Riemann Equations. Power series and its Radius of Convergence. Elementary idea of Mobius Transformation, Cross Ratio, Invariant Point and Critical point

Unit–III

Regular and Rectifiable Arcs. Contour. Domains: Connected, Simply Connected and Multiply Connected. Complex Line Integrals. Cauchy's theorem, Cauchy's Integral Formulae and Inequality. Morera's Theorem. Liouvelle's Theorem. Taylor and Laurent Series

Unit–IV

Singularities and Their Classification. Poles and Zeros of a Meromorphic Function, Argument Principle. Rouches Theorem. Fundamental Theorem of Algebra. Residues. Cauchy's Residue Theorem. Application of Cauchy's Residue Theorem for Evaluation of Integrals of Real valued Functions.

Books Suggested:-

1. Narayan, S. and Mittal, P.K. (2005). A Course of Mathematical Analysis. S. Chand.
2. Malik, S.C., & Arora, S. (2017). Mathematical Analysis. New Age International Publishers Pvt. Ltd.
3. Goyal, J.K., & Gupta, P.K. (2013). Functions of Complex Variable. Pragati Prakashan, Meerut.
4. Malik, S.C. (2018). Real and Complex Analysis. Jeevan Sons Publication, New Delhi.
5. Sharma, J.N. (2014). Functions of Complex Variable. Krishna Prakashan Media (P) Ltd.
6. Ahlfors, L. (2017). Complex Analysis. Mc Graw Hill.
7. Kasan, H.S. (2005). Complex Variables: Theory and Applications. PHI.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

20STA22C2 (Inference- I)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching Hours: 04 hrs per week.

Paper Code: 20STA22C2
Paper: Inference-I
Course Objectives

1 To understand basic theory of estimating population parameters
2 To learn the various properties of a good estimator
3 To understand the various methods of estimating parameters
4 To familiarize with how to find out critical region and best critical region
5 To Know the techniques of finding confidence interval based on small and large samples

Course Outcomes

1 Ability to estimate unknown parameters of a given probability distribution
2 Ability to understand the properties of a good estimator for Parameters of different Probability Distributions
3 Ability to obtain Critical Region (CR) and Best Critical Region (BCR)
4 Ability to apply MP Test, UMP Test, UUMP Test
5 Ability to understand the methods of obtaining confidence interval

Unit–I

Problem of Point Estimation: Properties of Estimators: Un-biasedness Consistency, Sufficiency, Neymann Factorization Theorem, Complete Sufficient Statistics, Efficiency, Minimum – Variance Unbiased (MVU) Estimators, Exponential Family of Distributions and its Properties, Cramer- Rao Inequality, Minimum Variance Bound (MVB) Estimators, Bhattacharya's Bounds.

Unit–II

Rao-Blackwell Theorem, Lehman Schefe's Theorem and its Applications in Finding Uniformly Minimum Variance Unbiased Estimators Methods of Estimation: Maximum Likelihood, Moments, Least Square, Minimum Chi- Square and Modified Minimum Chi- Square and Their Properties.

Unit–III

Neymann Theory of Testing of Hypotheses, Simple and Composite Hypotheses, Null and Alternative Hypotheses, Two Types of Errors, Critical Reason, Level of Significance, Power of The Test, Unbiased Tests, Critical Reason, N-P Lemma, Construction of Most Powerful Test, Uniformly Most Powerful Test, Uniformly Most Powerful Unbiasedness Tests.

Unit–IV

Likelihood Ratio Test: Derivation and its Properties, Asymptotic Distribution of L.R. Test. Interval Estimation: Method of Obtaining Confidence Intervals Based on Small and Large Samples. Unbiased and Shortest Expected Length Confidence Interval.

Books Suggested:-

1. Goon, A.M., Gupta, M.K., & Gupta B.D. (2013). Outline of Statistical Theory Vol. II. World Press
2. Rohatgi, V. K., & Saleh, A.K. Md. E. (2008). An Introduction to Probability and Statistics. Wiley.
3. Rao, C .R. (2002). Linear Statistical Inference and its applications. Wiley.
4. Gupta, S.C., & Kapoor, V.K. (2014). Fundamentals of Mathematical Statistics. Sultan Chand & Sons, New Delhi.
5. Kendall, M.G., & Stuart, A. (1979). Advanced Theory of Statistics. Charles Griffin & Co. Ltd.
6. Hogg, R.V., Tanis, E.A., & Zimmerman, D.L. (2019).Probability and Statistical Inference. Pearson.
7. Casella, G., & Berger, R.L. (2006). Statistical Inference. Cengage.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of

marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

20STA22C3 (Computer Programming using C++)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching Hours: 04 hrs per week

Paper Code: 20STA22C3
Paper: Computer Programming using C++
Course Objectives

1 To differentiate procedure Oriented Programming and Object Oriented Programmings
2 To learn the syntax and semantics of the C++ programming language
3 To learn how to overload functions and operators in C++
4 To learn concept of classes and objects
5 To learn object oriented programming concepts like inheritance, abstraction, encapsulation and polymorphism

Course Outcomes

1 Acquired knowledge about the improved version of C as object oriented langauge C++
2 Ablity to overload functions and operations in C++
3 Ability to Know the concept of friend functions, constructor, destructor
4 Able to apply inheritance, pointers, file operations and templates in developing programmes
5 Ability to develop C++ Programme to solve any mathematical as well as Statistical Problem

Unit–I

Basic concepts of Object Programming Problems (OOP), Advantages and Applications of OOP. Introduction to C++. Structure of a C++ Program. Creating the Source Files. Compiling and Linking, C++ Programming Basics: Input/Output, Data Types, Operators, Expressions, Control Structures, Library Functions, Functions In C++ : Passing Arguments to and Returning Values From Functions, Inline Functions, Default Arguments, Function Overloading.

Unit–II

Classes and Objects : Specifying and Using Class and Object, Arrays Within A Class, Arrays of Objects, Object As A Function Arguments, Friendly Functions, Pointers to Members, Constructors and Destructors. Operator Overloading and Type Conversions. Inheritance: Derived Class and Their Constructs, Overriding Member Functions.

Unit–III

Pointers to Objects, This Pointer, Pointers to Derived Classes, Virtual Functions, Streams, Stream Classes, Unformatted Input/ Output Operations, Formatted Console Input/ Output Operations, Managing Output with Manipulators, Opening and Closing A File. File Pointers and Their Manipulations, Error Handling During File Operations.

Unit–IV

Templates: Class Templates, Class Templates with Multiple Parameters, Function Templates, Overloading of Template Function, Member Function Templates. Manipulating String: Creating String Objects, Manipulating String Objects, Relational Operations, String Characteristics, Accessing Characters in Strings, Comparing and Swapping. Procedure Oriented Paradigms, Procedure Oriented Development Tools, Object Oriented Paradigm, Object Oriented Notations and Groups, Steps in Object Oriented Analysis and Design.

Books Suggested:-

1. Balagurusamy, E. (2017). Object Oriented Programming with C++. Tat Mc GrawHill.
2. Lafore, R. (2008). Object Oriented Programming in C++. Pearson Education India.
3. Schildt, H. (2017). C++: The Complete Reference. McGraw Hill Education.
4. Stroustrap, B. (2013). The C++ Programming Language. Pearson Addison-Wesley Professional.
5. Kanetkar, Y. (2003). Let us C++. BPB Publication.
6. Mitchell, R. (1995). C++ Object Oriented Programming. Springer.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of

16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

20STA22C4 (Sampling Techniques)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching Hours: 04 hrs per week

Paper Code: 20STA22C4
Paper: Sampling Techniques
Course Objectives

1 To give an account of the theoretical frame work of sample surveys and the methodology of sampling from finite populations
2 To learn concepts, definitions and notations, basic sampling schemes of Simple Random Sampling (SRS) and Stratified Sampling
3 To know the scheme of Systematic Sampling and to compare the SRS with Stratified and Systematic Samplings
4 To understand Multi-Stage and Multi-Phase Sampling Schemes
5 To achieve the knowledge of doing sampling with varying proabilities

Course Outcomes

1 Understand to plan the large scale nation-wide Indian National Sample Surveys
2 Able to identify and define the population to be studied, control of non-sampling errors
3 Understand the schemes of SRS and Stratified Sampling
4 Ability to use auxiliary information at the estimation stage
5 Understand the schemes of Cluster Sampling, Multi-Stage, Multi-Phase Sampling and PPS Sampling

Unit–I

Sample Versus Complete Enumeration. Designing of Sample Surveys, Sources of Errors In Sample Surveys, Types of Non-Response Errors Probability and Purposive Sampling, Simple Random Sampling with or without Replacement for The Estimation of Mean Total. Proportion and Ratio, Determination of Sample Size for Specified Precision Stratified Sampling: Proportional and Optimum Allocation. Estimation of Gain Due To Stratification. Construction of Strata and Determination of Number of Strata.

Unit–II

Ratio Estimates, Approximate Variance, Comparison with Mean Per Unit Estimate. Optimum Conditions, Bias of The Ratio Type Estimate, Unbiased Ratio Type Estimate Due to Hartley and Ross, Ratio Estimate in Stratified Sampling. Regression Estimators (Pre –Assigned and Estimated from the Sampling Comparison with the Ratio and Mean per Unit Estimates in Stratified Sampling.

Unit–III

Double Sampling (Two Phase Sampling) for Ratio and Regression Methods of Estimation. Systematic Sampling, Comparison with Stratified and Simple Random Sampling, Single Stage Cluster Sampling, and Variance in terms of Inter Cluster Correlation. Jessen'scost Function and Determination of Optimum Sampling Unit.

Unit–IV

Sampling with Varying Probability, Sampling with Probability Proportional to Size Lahiri Method of Selection Unequal Probability Sampling with Replacement and without Replacement Horvitz Thompson Estimator, its Variance and Unbiased Estimate of this Variance. Two Stage Sampling, Estimate of Population Mean and its Variance, Optimum Allocation for Fixed Cost.

Books suggested:-

1. Goon, A.M., Gupta, M.K., & Gupta, B.D. (2016). Fundamentals of Statistics, Vol-II. World Press.
2. Singh, D., & Chaudhary, F.S. (2018). Theory & Analysis of Sample Survey Designs. New Age International Private Limited.
3. Gupta, S.C., & Kapoor, V.K. (2014). Fundamentals of Applied Statistics. Sultan Chand & Sons.
4. Mukhopadhyay, P. (2008). Theory and Methods of Survey Sampling. PHI.
5. Chochran, W.G. (2007). Sampling Techniques. Wiley.

6. Sukhatem, P.V., & Sukhatme, B.V. (1970). Sampling Theory of Surveys with Applications. The Indian Society of Agricultural Statistics.
7. Raj, D., & Chandhok, P. (2013).Sample Survey Theory. Createspace Independent Pub.
8. Hansen, M.H., Hurwitz, W.N., & Madow, W.G. (1993). Sample Survey Methods and Theory. Wiley.

:

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

20STA22C5 (Applied Statistics-II)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching Hours: 04 hrs per week.

Paper Code: 20STA22C5
Paper: Applied Statistical-II
Course Objectives

1 To study the description and explanation of time series data
2 To know about the consistency in time series data by eliminating the effect of time series component (trend seasonal, cyclic and random variation)
3 To acquire knowledge about stationary, strong and weak stationary time series and different schemes and models
4 To impart skills for preparing control charts to control the quality of process and manufactured products
5 To study various acceptance and rejection sampling plans

Course Outcomes

1 Able to understand how the forecasting can be used in economic analysis
2 Acquainted with manufacturing process and specification
3 Obtained knowledge to drive the concept of auto-covariance, autocorrelation, box Jenkin's models estimation of parameters in ARIMA models
4 Acquired knowledge how to make a process stable in industries and other areas
5 Acquainted with the various acceptance and rejection sampling plans

Unit–I

Analysis of Time Series, Components of Time Series, Trend Measurement by Mathematical Curves: Polynomial, Growth Curves. Moving Average Method, Spencer's Formulae, Effect of Elimination of Trend on Other Components of Time Series. Variate Difference Method and its Use for Estimation of Variance of the Random Component. Measurement of Seasonal Fluctuations, Measurement of Cyclical Component; Periodogram Analysis.

Unit–II

Concept of Stationary Time Series, Strong and Weak Stationary: Auto Covariance and Auto Correlation. Correlogeam of Auto Regressive Scheme. Moving Average Scheme and A Harmonic Series. Box Jenkin's Models, Estimation of Parameters in ARIMA Models, Forecasting: Exponential and Adaptive Smoothing Models.

Unit–III

Statistical Quality Control and Its Purposes, 3 Sigma Control Limit, Shewart Control Chart. Control Charts For Variables and Attributes, Natural Tolerance Limits and Specification Limits: Modified Control Limits. Sampling Inspection Plan, Producer's and Consumer's Risk OC and ASN Function, AQL. LTPD and ATI.

Unit–IV

The Single, Double and Sequential Sampling Plans and Their Curves Viz AOQ, OC, ASN and ATI Carvers. The Choice Of Sampling Plans by Attributes and by Variables. Acceptance Plan by Variables, Single and Sequential Sampling Plans, Acceptance Sampling by Variables (Known and Unknown Sigma Case)

Books suggested:-

1. Kindall, M.G. (1973). Time Series. Hafner Press.
2. Goon, A.M., Gupta, M.K., & Gupta B.D. (2016). Fundamentals of Statistics, Vol-II. World Press.
3. Croxton, F.E., & Cowden, D.J. (1942). Applied General Statistics. Prentice-Hall, Inc.
4. Gupta, S.C., & Kapoor, V.K. (2014). Fundamental of Applied Statistics. Sultan Chand and Sons, New Delhi.
5. Grant, E.L. (1946). Statistical Quality Control. McGraw Hill.
6. Montgomery, D.C. (2008). Introduction to Statistical Quality Control. John Wiley and Sons.
7. Stuart, A. (2010). Kendall's Advanced Theory of Statistics – 3. Wiley.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

20STA22C6: Practical (Based on papers **20STA22C2** & **20STA22C3**) and will be of duration 3 hours.

Paper Code: 20STA22C6
Paper: Practical's (Inference I & Computer Programming) - 20STA22C2 & 20STA22C3

Course Objectives

1 To understand the estimation of population parameters in real life problems
2 To learn how confidence interval based on small and large samples be achieved
3 To discuss real life problems and conclude the result for best critical region
4 To learn the syntax and semantics of the C++ programming language
5 To learn how to overload functions and operators in C++

Course Outcomes

1 To understand how to make the error free C++ program using inheritance, abstraction, encapsulation and polymorphism
2 Ability to find out population parameters on the basis of sample
3 Ability to find out confidence interval and best critical region for practical problems
4 To Aquire Knowledge of improved version of C as object oriented langauge C++
5 Ability to Develop C++ Programme to solve any mathematical as well as Statistical Problem

20STA22C7: Practical (Based on papers **(Sampling Techniques and Applied Statistics-II) 20STA22C4** & **20STA22C5** and will be of duration 3 hours.

Paper Code: 20STA22C7

Course Objectives

1 To provide the method of sampling from finite populations and to estimate the population parameters
2 To estimate the mean, variance of the mean in case of simple random sampling and systematic sampling
3 To estimate the population mean and total, and their variances for stratified Random Sampling, Cluster Sampling and Multi Stage Sampling
4 To find out the component of time series by various methods
5 To understand how to make a process stable in industries and other areas by using control charts for attributes and variables. Also understand how to obtain ASN and OC functions of various sampling plans and plot them

Course Outcomes

1 Ability to work in practical frame work and methodology of sampling from finite populations
2 Able to estimate the population mean and variance of the estimator of the population mean in Simple Random Sampling
3 Understand how to estimate the population mean and population total and obtain their variances in case of Stratified Sampling, Cluster Sampling and other Sampling schemes
4 Ability to find out various component of time series by different methods
5 Ability to make control charts for attributes and variables to make process stable in industries and other areas. Ability to find ASN and OC functions of various sampling plans and plot them

The practical question paper will consist of five questions and the student will be required to attempt any three questions. The question paper will set on the spot jointly by the Internal and External Examiner.
Distribution of marks will be as follows: -

Marks for Question Paper	:	36
Marks for Practical Record book	:	06

Marks for Viva-Voice : 08
Total : 50

Semester III
21STA23C1 (Multivariate Analysis)

Max Marks- 80
Internal Assessment: 20
Time: 03 Hours
Teaching Hours: 04 hrs per week.

Paper Code: 21STA23C1
Paper: Multivariate Analysis
Course Objectives

1 To educate the extensions of univariate techniques to multivariate framework, multivariate normal distribution estimation, hypothesis testing
2 To perform analysis of multivariate data, such as to plot multivariate data, calculating descriptive statistics, testing for multivariate normality
3 To conduct statistical inference about multivariate means including hypothesis testing, different types of confidence intervals estimation
4 To undertake statistical analyses using appropriate multivariate techniques, which include Principal component, factor analysis, discriminant and clustering analyse
5 Knowledge about distinguish between dependence and interdependence methods in multivariate data analysis

Course Outcomes

1 Ability to work with multivariate data with normal distribution
2 Ability to analysis multivariate data with given mean vector. To test the hypotheses for mean correlation and regression coefficients
3 Ability to find major factors and the variability using multivariate techniques of Principal component, factor analysis discriminant and clustering analys
4 Ability to understand the characterstics of multivariate quantitative work including strengths and weeaknesses
5 Ability to evaluate the applicability of different models from a scientific perspective and judge what multivariate analysis techniques that are suitable to use in different environment

Unit–I

Multivariate normal distribution, Marginal and Conditional Distributions Characteristic Function, Distribution of Linear Combinations of Normal Vector, Random sampling from a multivariate normal distribution, Maximum likelihood estimators of Mean vector and Covariance Matrix. Distribution of sample mean vector, Distribution of Quadratic forms.

Unit–II

Wishart matrix - its distribution (without proof) and properties. Distribution of sample generalized variance, Null Distributions and uses of Simple, Partial and Multiple Correlation Coefficients. Hotelling's T^2 statistic –Derivation and its Null distribution Uses of T^2 statistic, Beheran - Fisher's Problem.

Unit–III

Multivariate Linear Regression Model. Estimation of parameters and their properties. Distribution of The Matrix of Sample Regression Coefficients, Test of Linear Hypothesis About Regression Coefficients, Multivariate Analysis of Variance [MANOVA] of One Way Classified Data. Wilk's Lambda Criterion, Likelihood Ratio Test Criteria for Testing Independence of Sets of Variables.

Unit–IV

Likelihood Ratio Criteria for Testing Equality of Covariance Matrices and Identity of Several Multivariate Normal Populations, Fisher's Discriminant Function, Mahalanobis' Distance, Principal Components, its Uses and Importance, Canonical Variables and Canonical Correlations.

Books suggested:-

1. Anderson, T.W. (2009). An Introduction to Multivariate Statistical Analysis. Wiley.
2. Rao, C. R. (2002). Linear Statistical Inference and its Applications. Wiley.
3. Johnson, R. A. and Wichern, D. W. (2002). Applied Multivariate Statistical Analysis. Prentice Hall of India.
4. Rencher, A. C. (2002). Methods of Multivariate Analysis. John Wiley & Sons.
5. Muirhead, R.J. (2005). Aspects of Multivariate Statistical Theory. Wiley.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

21STA23C2 (Designs of Experiments)

Max Marks: 80
Internal Assessment: 20
Time: 3 hrs.
Teaching hrs per week: 04 hrs per week.

Paper Code: 21STA23C2
Paper: Designs of Experiments
Course Objectives

1 To learn the issues and principles for the experimentation process & listing guidelines for designing experiments
2 To design the experiment for variability in one direction, two direction present in the experimental field
3 To analyse the data from the experimentation in which some of the units are not available due to some reasons
4 To design the experiments for testing the treatments which need large experimental unit using split plot and strip plot design
5 To carry out and analyse ANCOVA & Factorial Experiments with two factors and two levels for each factor

Course Outcomes

1 Ability to determine whether the design appropriately deals with extraneous variables via controlling the value of a variable, blocking on such a variable, replication and randomization.
2 Able to layout and analyse the experiment for one directional variation and two directional variation
3 Ability to estimate the missing observations and then analyse the data
4 Ability to layout the experiments for split plot and strip plot designs and to carry out their analyses
5 Ability to allocate treatments in factorial experiments with two levels. Analyse it using Yate's technique. Understand to perform ANCOVA

Unit–I

Linear Models: Standard Gauss Markov Models, Estimability of Parameters, Best Linear Unbiased Estimator (BLUE), Method of Least Squares, Gauss-Markov Theorem, Variance- Covariance Matrix of Blues.

Unit–II

Analysis of Variance for One- Way, Two -Way With One/M Observations Per Cell for Fixed, Mixed and Random Effects Models, Tukey's Test for Non- Additively. General Theory of Analysis of Experimental Designs; Completely Randomized Design, Randomized Block Design and Latin Square Designs, Missing Plot Techniques in RBD and LSD,

Unit–III

Analysis of Covariance for CRD and RBD.Split Plot and Strip Plot Designs. General Factorial Experiments: Definition, Estimation of Factor's Effect. Analysis of The Factorial Experiments Using CRD and RBD. Confounding and Partial Confounding.

Unit–IV

Incomplete Block Designs; Balanced, Connectedness, Orthogonality and Resolvability. Balanced Incomplete Block Design With and Without Recovery of Inter Block Information, Youden Squares.

Books suggested:-

1. Dass, M.N., & Giri, N.C. (2017). Design and analysis of Experiments. New Age International.
2. Dey, A. (1987). Theory of Block Designs. Wiley–Blackwell.
3. Raghavrao, D. (2002). Construction and combinatorial problems in design of experiments. Dover Publications Inc.
4. Gupta, S.C., & Kapoor, V.K. (2014). Fundamentals of Applied Statistics. Sultan Chand & Sons.
5. Montgomery, D.C. (2013). Design and analysis of Experiments. Wiley.
6. Goon, A.M., Gupta, M.K., & Gupta B.D. (2013). Outline of Statistical Theory Vol. II. World Press.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

21STA23C3 (Optimization Techniques-I)

Maximum Marks: 80
Internal Assessment Marks: 20
Time: 3 Hours
Teaching Hours: 4 Hours per week

Paper Code: 21STA23C3
Paper: Optimization Techniques-I
Course Objectives

1 To Understand Basic Terms to be used in Linear Programming
2 To Know the formulation techniques of the problems as Linear Programming Problems
3 To Understand Procedures for Obtaining Optimal Solutions of LPP
4 To understand the need and origin of the optimization Techniques
5 To Acquire Knowledge about the Solutions of Transportation and Assignment Problems

Course Outcomes

1 Able to understand the importance of extreme points in obtaining the optimal solution
2 Acquainted with the formulation of the real life problems as Linear Programming Problems (LPP)
3 Able to use techniques for obtaining optimal solution of the problems of LPPs
4 Acquired knowledge for achieving optimal solutions of the Transportation and Assignment Problems
5 Enhanced computing power for determining alternate solutions of the LPP

Unit–I

Convex Sets and Functions. Linear Programming Problems: Formulation, Examples and Forms. Properties of a Solution to the LPP. Development of Optimum Feasible Solution. Solution of LPP by Graphical and Simplex Methods. Solution of Simultaneous Equations by Simplex Method.

Unit–II

Artificial Variable Techniques: Big-M-Method and Two Phase Simplex Method. Degeneracy in LPP and its Resolution. The Revised Simplex Method. Duality in LPP: Symmetric and Un-Symmetric Dual Problems. Fundamental Duality Theorem. Complementary Slackness Theorem. Dual Simplex Method. Economic Interpretation of Duality.

Unit–III

Post- Optimization Problems: Sensitivity Analysis and Parametric Programming. Integer Programming Problems(IPP). Gomory's Algorithem for Pure Integer Linear Programs. Solution of IPP by Branch and Bound Method. Applications of Integer Programming.

Unit–IV

Transportation Problems: Mathematical Formulation and Fundamental Properties. Initial Basic Feasible Solution by North West Corner Rule, Lowest Cost Entry Method and Vogel's Approximation Method. Optimal Solution of Transportation Problems. Assignment Problems: Mathematical Formulation and Solution by Hungarian Assignment Method. Reduction Theorem. Sensitivity in Assignment Problems.

Books suggested:-

1. Gass, S.I. (2010). Linear Programming: Methods and Applications. Dover Publication.
2. Kambo, N.S. (1984). Mathematical Programming Techniques. Affiliated East-West Press.
3. Sinha, S.M. (2010). Mathematical Programming - Theory and Methods. Elsevier.
4. Bazaraa, M.S., Jarvis, J.J., & Sherali, H.D. (2011). Linear Programming and Network Flows. Wiley.
5. Hadley, G. (2002). Linear Programming. Narosa.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

Optional Papers:
21STA23D1 (a) (Stochastic Processes)

Maximum Marks: 80
Internal Assessment Marks: 20
Time: 3 Hours
Teaching Hours: 4 Hours per week

Paper Code: 21STA23D1
Paper: (a) Stochastic Processes
Course Objectives

1 To understand the Application of the Probability Theory in Stochastic Processes
2 To understand the use of probability generating functions
3 To acquire knowledge about Markov Chain
4 To Gain Knowledge about Poisson Process, Branching Process and Reniewal Process
5 To understand Random Walk

Course Outcomes

1 Able to understand the use of probability generating functions
2 Acquired Knowledge about Different Types of Stochastic Processes
3 Demonstrate ability to the basic concepts of theory of Markov Chain
4 Obtained understanding for the solution of stochastic differential equations
5 Gained Skills to Obtain Probability of Ultimate Extinction and duration of the Game

Unit–I

Probability Generating Function: Binomial, Poisson, Geometric and Negative Binomial Distributions. Bi-variate Probability Generating Function. Stochastic Processes: Definition, Classification and Examples. Compound Distributions: Mean, Variance and Examples.

Unit–II

Markov-Chains: Classification of States and Chain, Chapman-Kolmogorov Equation, Higher Transition Probabilities, Stability of Markov Systems and Limiting Behaviour. Poisson Process: Classifications, Decomposition and Related Distributions and Generalization.

Unit–III

Birth and Death Processes: Yule-Furry Process and Generalization. Linear Birth-Death Process Branching Processes: Properties of Generating Functions, Probability of Extinction and Distribution of Total Progeny. Random Walk: First Passage Time, Gambler's Ruin Problem and Duration of the Game.

Unit–IV

Renewal Processes: Renewal Process in Discrete & Continuous Time, Forward Renewal Equation, Renewal Function and Density, Renewal Theorems, Central Limit Theorem for Renewal Process, Delayed and Equilibrium Renewal Process, Residual and Excess Life Times Renewal Process, Poison Process as a Renewal Process.

Books Suggested:-

1. Medhi, J. (2019). Stochastic Processes. New Age International.
2. Baily, N.T.J. (1990). The Elements of Stochastic Processes with Applications to the Natural Sciences. Wiley-Interscience.
3. Bhatt, B.R. (2000). Stochastic Models, Analysis and Application. New Age International Pvt. Ltd.
4. Cox, D.R., & Miller, H.D. (2001). The Theory of Stochastic Processes. Chapman and Hall/CRC.
5. Harris, T.E. (1963). The Theory of Branching Processes. Springer.
6. Pinsky, M., & Karlin, S. (2010). An Introduction to Stochastic Modeling. Academic Press.

7. Karlin, S., & taylor, H. (2012). A First Course in Stochastic Process. Academic Press.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

21STA23D2 (b) (Agricultural Statistics)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching hours: 04 hrs per week.

Paper Code: 21STA23D2
Paper: (b) Agricultural Statistics

Course Objectives

1 To impart training for collecting the agriculture statistics
2 To acquire knowledge regarding methods for planning improvement and evaluation of Agricultural Research & development
3 To help the economists for study the comparative merits of the survey and the cost accounting methods
4 To aware about the concept of the Breeding Value, Genetic Variance and regular system of Inbreeding
5 To study the Equilibrium in Large Populations

Course Outcomes

1 Able to understand and analyze the current issues and events that are occurring in agriculture
2 Able to understand how employer characteristics and decision-making at various levels enhance the success of an agricultural enterprise
3 Able to demonstrate critical thinking and problem solving skills as they apply to a variety of animal and or plant production systems
4 Able to understand genetic variance
5 Updated knowledge about utilization and growth trends of agricultural commodities

Unit–I

History of Agricultural Development in India. Current Production Utilization and Growth Trends of Agricultural Commodities In India. Crop Improvement: Plant Breeding Traditional and Contemporary Methods, Plant Classification, Description and Economic Use of Field Crops. Biotechnological Tools for Crop Improvement, Plant Genetics Resources, Seed Quality Control, Seed Production Methods, Seed Sowing Methods, Seed Stages. Crop Production: Modern Approaches of Management of Pest and Disease, Principles of Plant Pathology.

Unit–II

Plant Science: Metabolic Processes and Growth Regulation, Climate Change, Reproduction, Post Harvest Physiology, Soil Environment Microbiology, Bio-Fertilizer. Useful Organism: Honey Bees and Bee Keeping, Lack Insect and Silk Worm. Horticulture: Fundamental of Horticulture, Orchards Management, Breeding of Horticultural Crops, Improvement of Fruit and Plantation Crops. Importance of Fruits and Vegetables In Human Nutrition. Contribution of Horticulture In National Economy and Export.

Unit–III

Some Basic Genetical Terms, Statistical Analysis of Segregation, Detection and Estimation of Linkage. Gene and Genotypic Frequencies. Random Mating and Equilibrium In Large Populations. Disequilibrium Due To Linkages for Two Pairs of Genes and for Sex Linked Genes. Selection, Mutation and Migration. Equilibrium Between forces In Large Population. Polymorphism. Fisher's Fundamental Theorem of Natural Selection.

Unit–IV

Polygenic Systems for Quantitative Characters, Concepts of Breeding Value, Dominance, Average Effect of Gene and Epistatic Interactions. Genetic Variance and Its Partitioning. Correlation Between Relatives. Regular System of Inbreeding, Effects of Inbreeding. Genotype and Environment Interaction, Stability Parameters.

Books suggested:-

1. Falconer, D.S., & Mackay, T.F.C. (1995). Introduction to quantitative Genetics. Longman.

2. Kempthrone, O. (1969). An Introduction to Genetic Statistics. Iowa State University Press.
3. Narain, P. (1990). Statistical Genetics. New Age International Pvt. Ltd.
4. ICAR. Handbook of Agriculture. ICAR publication.
5. Jain, J.P. (2017). Statistical Technique in Quantitative Genetics. Hindustan Publishing Corporation.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

21STA23D3 (c) (Methods of Operations Research)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching Hours: 04 hrs per week

Paper Code: 21STA23D3
Paper: Methods of Operations Research
Course Objectives

1 To provide the basic knowledge about Operation Research and different methods
2 To understand the policy of replacement of items due to deterioration and fails completely, recruitment and promotion problems
3 To understand inventory problems and to develop inventory models
4 To obtain job sequencing methods and simulation models
5 To understand the principles associated with effective project management

Course Outcomes

1 Ability to take optimum decisions/ solution to the executive type problems
2 Able to form and solve deterministic and probabilistic inventory models and purchase inventory models with one, two and any number of price break
3 Ability to solve job sequencing problem of N jobs through 2, 3 and M machines
4 Ability to use process of simulation in inventory, queuing, finance etc.
5 Ability to use CPM and PERT methods in effective project management and how the crashing is done.

Unit–I

Definition and Scope of Operations Research and Its Role In Decision-Making, its Characteristics, Phases, Different Types of Models, Their Construction and General Methods of Solution .Replacement Problem, Replacement of Items That Deteriorate, Replacement of Items That Fails Completely Individual Replacement Policy : Motility Theorems, Group Replacement Policy, Recruitment and Promotion Problems.

Unit–II

Inventory Problems, Costs Involved In Inventory Problems, Classification of Inventory System. Deterministic and Probabilistic Inventory Models, Purchase Inventory Model, Purchase Inventory Model with One, Two and Any Number of Price Break.

Unit–III

Job Sequencing Problems; Introduction and Assumption, Processing of N Jobs Through Two Machines(Johnson's Algorithm) Processing of N Jobs Through Three Machines and M Machines, Processing Two Jobs Through N Machines(Graphical Method) Simulation Definition, Types, Uses and Limitation of Simulation Phases, Simulation Models, Monte Carlo Simulation, Application of Simulation.

Unit–IV

PERT/CPM: Development Uses and Application of PERT/CPM Techniques, Network Diagram Representation .Fulkerson 1-J Rule for Labeling Time Estimate and Determination of Critical Path On Network Analysis, PERT Techniques, Crashing.

Books suggested:-

1. Sharma, S.D. (2012). Operation Research. Kedar Nath Ram Nath.
2. Taha, H.A. (2014). Operations Research: An Introduction. Pearson.
3. Sharma, J.K. (2017). Operations Research: Theory and Applications. Laxmi Publication.
4. Gupta, R.K. (2010). Operations Research. Krishna Prakashan Media.

5. Churchman, C.W. (1957). Introduction to Operations Research. John Wiley and Sons.
6. Iyer, P.S. (2008). Operations Research. Mc Graw Hill.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

21STA23C4- Practicals (Based on **21STA23C1**) and will be of duration 3 hours.

Paper Code: 21STA23C4
Paper: Practical's (Multivariate Analysis)- 21STA23C1

Course Objectives

1 To learn the extensions of univariate techniques to multivariate framework, such as multivariate normal distribution, estimation, hypothesis testing
2 To perform analysis of multivariate data, such as plot multivariate data, calculating descriptive statistics, testing for multivariate normality
3 To conduct statistical inference about multivariate means including hypothesis testing, confidence intervals estimation
4 To understand the procedure of finding the principal components by examples
5 To conduct the difference between dependence and interdependence methods in multivariate data analysis with examples

Course Outcomes

1 Ability to obtain mean vector and var-car matrix for multivariate data
2 Ability to find the estimate of population mean vector and dispersion matrix for multivariate normal distribution
3 Know how to test the hypothesis for mean of multivariate population and to obtain confidence interval for it
4 Ability to test hypothesis for correlation coefficient and regression coefficient for Null population
5 Ability to tackle the problem of principle components

21STA23C5 -Practicals (Based on **21STA23C2))** and will be of duration 3 hours.

Paper Code: 21STA23C5
Paper: Practical's (Designs of Experiments)- 21STA23C2

Course Objectives

1 To analyse one way classified data, two way classified data and to find out Critical Difference
2 To analyse CRD, RBD and LSD
3 To analyse the data from the experimentation with missing observations
4 To analyse design with Factorial Experiments for testing the Main Effects and Interaction Effects for two levels
5 To analyse Split-Plot Design and Strip-Plot Design. To perform ANCOVA

Course Outcomes

1 Ability to perform ANOVA for one way classified data and two classified data. Learnt to find out the Critical Difference and the varibility in case of random effect model
2 Able to analyse data obtained from CRD, RBD and LSD
3 Ability to estimate the missing observations and then analyse the data
4 Ability to perform the analysis of data obtained from Split Plot and Strip Plot Designs
5 Ability to perform analysis of variance using factorial experiments with two levels upto four factors using Yate's technique

The question paper will consist of five questions and the student will be required to attempt any three questions. The question paper will set on the spot jointly by the Internal and External Examiner.
Distribution of marks will be as follows: -
Marks for Question Paper : 36

Marks for Practical Record book	:	06
Marks for Viva-Voice	:	08
Total	:	50

Semester IV
21STA24C1 (Econometrics)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching Hours: 04 hrs per week.

Paper Code: 21STA24C1
Paper: Econometrics
Course Objectives

1 To know the classical linear regression model, its assumptions and the consequences of their violation
2 To understand OLS estimators and their properties
3 To understand problems of equation specification and functional form
4 To understand the consequences of multicollinearity and possible solutions
5 To understand how to test for and resolve problems of autocorrelation, non-normality and hetroscedasticity

Course Outcomes

1 Obtained theoretical background for the standard methods and properties of OLS
2 Acquired knowledge about regression analysis for analysing the data
3 Know elementary procedures for model validation in the single equation context
4 Became familiar with the concept of multicollinearity, autocorrelation and how to resolve them
5 Acquainted with the concepts of Non-normality & Hetrosecdasticity and how to resolve them

Unit–I

Two Variable Linear Regression Model- Least Squares Estimators of Coefficients and Their Properties, Inference In Least Squares Model, The General Linear Regression Model, Ordinary Least Squares Estimator and Its Properties, Inference In General Linear Regression Model. Generalized Least Squares Estimation

Unit–II

Tests of Linear Restrictions On Regression Coefficients, Use of Extraneous Information On Regression Coefficients – Restricted Regression, Restricted Least Squares and Its Properties, Mixed Regression and Properties of Mixed Regression Estimator, Specification Errors Analysis- Inclusion and Deletion of Explanatory Variables, Effect On Estimation of Parameters and Disturbance Variance.

Unit–III

Heteroscedasticity, Tests for Heteroscedasticity – Bartletts's, Breusch-Pagan and Goldfeld Quand t Tests Multicollinearity - Exact and Near Multicollinearity, Consequences and Detection of Multicollinearity , Farrar Glauber Test, Remedies for Multicollinearity, Ridge Regression Autocorrelation , Sources and Consequences, AR(1) Process Tests for Autocorrelation, Durbin Watson Test, Errors In Variables Model, Instrumental Variable Method of Estimation.

Unit–IV

Simultaneous Equations Models: Structural and Reduced forms, Identification Problem. Rank and Order Conditions of Identification, Restrictions On Structural Parameters. Estimation In Simultaneous Equations Models: Recursive Systems, Indirect Least Squares 2SLS Estimators, Limited Information Estimators, K-Class Estimators,

Books suggested:-

1. Johnston, J. (1984). Econometric Methods. McGraw-Hill, New York.
2. Gujarati, D. N. (2004). Basic Econometrics. Tata McGraw Hill.
3. Koutsyannis, A. (2004). Theory of Econometrics. Macmillan Publishers Limited
4. Maddala, G.S., & Lahiri, K. (2012). Introduction to Econometrics. Wiley.
5. Madnani, GMK. (2015). Introduction to Econometrics: Principles and Applications. Oxford & IBH Publishing Co Pvt.Ltd.

6. Judge, G.G., Griffiths, W.E., Hill, R.C., Lütkepohl, H., & Lee T-C. (1985).Introduction to the Theory and Practice of Econometrics. Wiley.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

21STA24C2 (Inference- II)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching Hours: 04 hrs per week

Paper Code: 21STA24C2
Paper: Inference-II
Course Objectives

1 To know the theory of Sequential Test Procedures, OC and ASN functions
2 To derive ASN and OC functions of SPRT
3 To understand the basic terminology of decision theory and to find out Optimal, Bayes & Minimum Decision Rules
4 To know the concept of Non Parametric Theory of Order Statistics and their distributions
5 To understand the hypothesis testing of one sample and two samples for location problem

Course Outcomes

1 Ability to test hypothesis using sequential procedure
2 Ability to determine ASN and OC functions of SPRT
3 Have the knowledge of Decision Function, Admissible Decision Rules, Risk function and Average Risk function, Bayes' risk and Minimax Risk
4 Know the pdf of Order Statistics & functions of Order Statistics, and also the Asymptotic Distribution of Order Statistics
5 Understand to test for one sample location problem using Sign test, Wilcoxom- Sign Test, K-S test and also to test for two samples location problem using K-S two samples test, Wald-wolfowitz test, Mann-Whiteney U test

Unit–I

Sequential Analysis; Sequential Testing Procedure, OC and ASN Functions, Wald's SPRT, Strength of SPRT and Determination of Its Stopping Bounds, Stopping Rule. Determinations of OC and ASN Functions of SPRT, Wald's Fundamental Identity and Its Use In The Derivation of ASN Function of SPRT.

Unit–II

Basic Elements of Decision Theory: Decision Function, Risk Function, Rand omization, Optimal Decision Rules: Baye's and Minimax Decision Rule, The Least Favorable Distribution , Convex Loss Function. The form of Bayes Rules for Estimation Admissibility and Completeness. Existence of Minimal Complete Class.

Unit–III

Non Parametric Theory: Concept of Non Parametric and Distribution Free Methods, Order Statistics , Their Marginal and Joint Distributions. Distributions of Median, Range and Coverage; Moments of Order Statistics. Asymptotic Distribution of Order Statistics.

Unit–IV

Non Parametric Tests: One Sample and Paired Sample Problems. Ordinary Sign Test, Wilcoxon Signed Ranked Test, and Their Comparison. General Problem of Tied Differences. Goodness of Fit Problem : Chi-Square Test and Kolmogrov – Smirnov One Sample Test, and Their Comparison. Two Sample Problems: K-S Two Sample Test, Wald – Wolfwitz Run Test, Mann –Whiteney U Test, Median Test.

Books suggested:-

1. Goon, A.M., Gupta, M.K., & Gupta B.D. (2013). Outline of Statistical Theory Vol. II. World Press.
2. Kendall, M.G., & Stuart, A. (1979). Advanced Theory of Statistics. Charles Griffin & Co. Ltd.
3. David, H.A., & Nagaraja, H.N. (2003). Order Statistics. Wiley.
4. Siegel, S., & Castellan, N.J. (1988). Nonparametric Statistics for Behavioral Sciences. McGraw-Hill Education.

5. Mukhopadhayaya, P. (2016). Mathematical Statistics. Books and Allied.
6. Gibbons, J.D., & Chakraborty, S. (1992). Nonparametric Statistical Inference. Marcel Dekker.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

21STA24C3 (Optimization Techniques-II)

Maximum Marks-80
Internal Assessment Marks-20
Time-03 Hours
Teaching Hours- 04 hrs per week

Paper Code: 21STA24C3
Paper: Optimization Techniques-II
Course Objectives

1 To understand games theory with applications as LPP
2 To know about the formulation of the real life problems as NLPP
3 To acquire knowledge about the necessary and sufficient conditions for the solutions of NLPP
4 To acquaint with different solution procedures of NLPPs
5 To study the applications of dianamic, goal and stochastic linear programming

Course Outcomes

1 Acquired knowledge for the solutions of Games by LPP techniques
2 Able to describe and formulation Non Linear Programming Problems (NLPP)
3 Able to understand the difference between NLPP and LPP
4 Acquainted with the methods for the solution of NLPP
5 Able to obtain approximate solutions of restricted problems

Unit–I

Theory of Games: Characteristics of Games, Minimax (Maximin) Criterion and Optimal Strategy. Solution of Games with Saddle Point. Equivalence of Rectangular Game and Liner Programming. Fundamental Theorem of Game Theory. Solution of mxn Games by Linear Programming Method. Solution of 2X2 Games without Saddle Point. Principle of Dominance. Graphical Solution of (2xn) and (mx2) Games.

Unit–II

Non-Liner Programming Problems (NLPP): Formulation of NLPP. Kuhn-Tucker Necessary and Sufficient Conditions of Optimality, Graphical Solution of an NLPP. Quadratic Programming Problems : Wolfe's and Beale's Method of Solutions

Unit–III

Separable Programming and its Reduction to LPP. Separable Programming Algorithm. Geometric Programming: Constrained and Unconstrained. Complementary Geometric Programming Problems. Fractional Programming and its Computational Procedure

Unit–IV

Dynamic Programming: Balman's Principle of Optimality. Application of Dynamic Programming in Production, Linear Programming and Reliability Problems. Goal Programming and its formulation .Stochastic Linear Programming.

Books Suggested:-

1. Kambo, N.S. (1984). Mathematical Programming Techniques. Affiliated East-West Press.
2. Sinha, S.M. (2010). Mathematical Programming - Theory and Methods. Elsevier.
3. Bellman, R. (2003). Dynamic Programming. Dover Publications Inc.
4. Bellman, R.E., & Dreyfus, S.E. (2016). Applied Dynamic Programming. Princeton University Press.
5. Mitra, G. (1976). Theory and Applications of Mathematical Programming. Academic Press Inc.

6. Bazaraa, M.S., Sherali, H.D., & Shetty, C.M. (2006).Nonlinear Programming: Theory and Algorithms. Wiley.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

Optional Paper
21STA24D1 (a) (Queuing Theory)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching hours: 04 hrs per week

Paper Code: 21STA24D1
Paper: (a) Queuing Theory
Course Objectives

1 To understand the use of Probability theory and applications of Stochastic Processes in solving real life problems
2 To understand the terminology and characterstics of Queuing Systems
3 To Acquire Knowledge about Markovian Singal Server, Finite Server and Infinite Server Queues
4 To Acquaint with Bulk Queuing Markovian Models and Non-Markovian Queuing Models
5 To aware about the methods for obtaining steady-stated solutions of Queuing Models

Course Outcomes

1 Able to understand basic characteristic features of a queuing system and analytical techniques for queuing models
2 Attained knowledge to understand probabilistic models with applications in science and engineering
3 To analyze a network of queues with Poisson external arrivals and exponential service requirements
4 Gained knowledge to formulate stochastic problems in terms of differential equations and their steady state solutions
5 Able to Analyse different queuing models with singal and multiple servers having Markovian and non-Markovian arrivals and services

Unit–I

Queuing Process: Notations, Measures of Effectiveness and Characteristics, Little's Law, Applications of Poission Process and Exponential Distribution. M/ M/ 1 and M/M/I/R Models with Steady State Solution, Waiting Time Distribution, Measures of Effectiveness and Limited Waiting Space.

Unit–II

Parallel Channels Queues. M/M/C Model Steady State Solution, Waiting Time Distribution and with limited Waiting Space. Queues with Parallel Channels of Truncation. M/M/C/K and M/M/ ∞ Models. Queues with Finite Waiting Capacity with Impatient Customers: Balking and Reneging. Machine Interference Problem.

Unit–III

Bulk System with Input and Output Service. Bulk Models: $M^{(x)}$/ M/ 1 , M/ $M^{(y)}$/ 1, M/ M $^{(a,b)}$ / 1, M /E_K / 1and E_K / M/ 1 with Waiting Time Distributor and Steady State Solutions. Priority Queue Discipline. Networks of Queues, Open and Closed Queuing Networks; Queues with Vacations, Markov-Modulated Queuing Systems.

Unit–IV

Non Markovian Queues: Imbedded Markov Chain. M/G/1, G/M/1 and M/G $^{(a,b)}$/ 1 Models with Steady State Solutions and Waiting Time Distribution. Supplementary Variables Technique: M/G/1 and M/G $^{(b)}$/ 1 Queuing Models.

Books Suggested:-

1. Gross, D., Shortle, J.F., Thompson, J.M., & Harris, C.M. (2013). Fundaments of Queuing Theory. Wiley.
2. Kashyap, B.R.K., & Chaudhary, M.L. (1988). An Introduction to Queuing Theory. A. & A. Publications.

3. Kleinrock, L. (1975). Queuing Systems. Wiley-Interscience.
4. Medhi, J. (1991). Stochastic Models in Queuing Theory. Academic Press Inc.
5. Cooper, R.B. (1981). Introduction to Queuing Theory. North Holland.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

21STA24D2 (b) (Actuarial Statistics)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching hours: 0 hrs per week

Paper Code: 21STA24D2
Paper: (b) Acturial Statistics
Course Objectives

1 To learn the applications of Statistics and Probability in Insurance, Pension Plans and other Investment Areas
2 To understand the basic concepts and statistical methods applicable in actuarial science
3 To provide an exposure to the basic models of insurance processes
4 To aware the techniques for estimation of possible losses to the insured persons
5 To acquire the knowledge of Reserve benefits

Course Outcomes

1 Able to understand the basic actuarial models
2 Acquired skills for the applying the methods of actuarial science in insurance and risk management
3 Provided ample scope for employment in the insurance and financial sectors
4 Acquainted with the applications of Statistics and Probability in Insurance, Pension Plans and other Investment Areas
5 Gained the Knowledge of Reserve Benefits

Unit-I

Utility Theory: Utility Function, Expected Value Principle, Expected Utility Criterion, Types of Utility Function, Insurance and Utility Theory. Survival Distribution and Life Tables: Survival Function, Curtate Future Lifetime, Force of Mortality, Assumptions for Fractional Ages, Some Analytical Laws of Mortality. Life Tables and its Relation with Survival Function, Select and Ultimate Tables. Multiple Life Functions, Joint Life and Last Survivor Status, Insurance and Annuity Benefits Through Multiple Life Functions

Unit-II

Multiple Decrement Models, Deterministic and Random Survivorship Group. Individual Risk Models: Models for Aggregate Claims, Sum of Independent Claims, Approximations and Their Applications. Collective Risk Models: Models for Aggregate Claims, Compound Poisson Distribution and its Properties. Principle of Compound Interest: Nominal and Effective Rates of Interest and Discount, Force of Interest and Discount, Compound Interest, Accumulation Factor, Continuous Compounding, Present Value of a Future Payment.

Unit-III

Life Insurance: Insurance Payable at the Moment's of Death and at the End of the Year of Death-Level Benefit Insurance, Endowment Insurance, Differed Insurance and Varying Benefit Insurance Recursion. Life Annuities: Single Payment, Continuous Life Annuities, Discrete Life Annuities, Life Annuities with Monthly Payments, Varying Annuities Recursions, Complete Annuities- Immediate and Apportion-able Annuities. Reinsurance and its Different Types

Unit-IV

Principles of Premium Calculation: Continuous and Discrete Premiums, True Monthly Payment Premiums, Apportion-able Premiums. Net Premium Reserves: Continuous and Discrete Net Premium Reserve, Reserves on a Semi-Continuous Basis, Reserves Based on True Monthly Premiums, Reserves

on an Apportion-able or Discounted Continuous Basis, Reserves at Fractional Duration. Commutation Function and Accumulation Type Benefits. Recursive Formulae for Reserves Commutation Function. Allocation of Loss to Policy Years. Premiums that Include Expenses General Expenses and Types of Expenses Per Policy.

Books Suggested:-

1. Dickson, C. M. D. (2005). Insurance Risk and Ruin (International Series no. 1 Actuarial Science), Cambridge University Press
2. Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A., & Nesbitt, C.J. (1997). Actuarial Mathematics. Society of Actuaries, Itasca, Illinois, U.S.A.
3. Rotar, V.I. (2015). Actuarial Models: The Mathematics of Insurance, 2nd ed., CRC Press, New York.
4. Klugman, S. A., Panjer, H. H., Willmotand, G. E., & Venter, G. G. (2008). Loss Models: From Data to Decisions. Wiley-Interscience
5. Borowaik, D.S., & Shapiro, A.F. (2005): Financial and Actuarial Statistics: An Introduction, Marcel Dekker Inc., New York-Basel
6. Promislow, S.D. (2011). Fundamentals of Actuarial Mathematics. Wiley.
7. Spurgeon, E.T. (2011). Life Contingencies, Cambridge University Press.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

21STA24D3 (c) (Clinical Trials)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching Hours: 04 hrs per week

Paper Code: 21STA24D3
Paper: (c) Clinical Trials

Course Objectives

1 To understand some frequently used terms in health profession for foundation of Clinical Trials.
2 To acuaint with the outlines of the essential design issues of randomized clinical trials for the four phases
3 To identify and classify different types of designs in Pharmaceuticals Experiments
4 To understand the basic statistical principles, concepts, methods for clinical data analysis and testing of hypothesis
5 To know the philosophy of data base, data monitoring and regulatory affairs

Course Outcomes

1 Ability to understand some frequently used terms in Clinical Trials
2 Ability to understand the essential design issues of Randomized Clinical Trials
3 Ability to identify and classify different types of designs used in Pharmaceuticals Experiments
4 Ability to identify and classify different types of trial designs when reading a trial report
5 Ability to understand the basic statistical principal, concepts and methods for Clinical Trials data analysis and reporting

Unit–I

Introduction, Motivation, and Ethics of Clinical Trials: Historical examples, Introduction to study designs and clinical trials, Ethics and Historically derived principles, Nuremberg Code, Declaration of Helsinki, Belmont Report. Equipoise, Informed consent. Phases, Contexts, Examples: Description of trial phases, Trial contexts and examples, Study Protocol: Introduction, background, Objectives ,Eligibility, Design, Rand omization, Intervention details, assessments and data collection, case report forms, Violations, Amendments. The Study Population and Cohort: Study population, Study cohort, Recruitment, Accrual, Inclusiveness and Representation .

Unit–II

Study/Trial Design: Phase I designs, Dose-finding designs,Phase II designs, Pilot studies, Single arm ,Historical control designs,Phase III designs,Factorial designs,Crossover designs,Multicenter studies,Pilot studies,Phase IV designs. Treatment Allocation: Rand omization, Simple ,Blocked, Stratified,Adaptive allocation, Masking.

Unit–III

Statistical Perspective: Philosophy, Bayesian vs. Frequentist. Research Question and Outcomes: Research Question, Surrogate Outcomes. Measurement and Data Capture: Measures and endpoints, Required observations,Types of measures, baseline measurements, Case report forms , Data collection, Paper or electronic, Parsimony, Database and software, Staffing and resources.

Unit–IV

Data Monitoring, Trial Conduct: Data quality assurance, Data delinquency, Data Monitoring, Trial Conduct, Occurrence and control of variation and bias. Introduction to Power and Sample Size: Hypothesis testing, P-values, confidence intervals, General power/sample size, estimating effect size, Matching sample size calculations to endpoints. Regulatory Affairs: Misconduct and fraud Conflict of interest.

Books Suggested:-

1. Piantadosi, S. (2017). Clinical Trials: A methodological Perceptive. Wiley.
2. Friedman, L.M., Furberg, C.D., DeMets, D., Reboussin, D.M., & Granger, C.B. (2015). Fundamentals of Clinical Trials. Springer.

3. Fleiss, J.L. (1999). Design and Analysis of Clinical Experiments. Wiley.
4. Marubini, E., & Valsecchi, M.G. (2004). Analysing Survival Data from Clinical Trials and Observational Studies. Wiley.
5. Jennison, C., & Turnbull, B.W. (1999). Group Sequential with Application to Clinical Trials. Chapman and Hall/CRC Press.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

21STA24CL3- Practicals (Based on **21STA24C3)** and will be of duration 3 hours.

Paper Code: 21STA24CL3
Paper: Practical's (Optimization Techniques-II-21STA24C3)

Course Objectives

1 To understand formulation methods for the game problems as LPP
2 To acquire computational knowledge for the solution of games as LPP
3 To gains skills for obtaining solutions of NLPP by different methods
4 To learn the use of software for the solutions of NLPPs
5 To understand the applications of NLPs in real life

Course Outcomes

1 Achieved experienced for the use of LPP techniques to solve games problems
2 Able to understand computational techniques for the solutions of NLPP'S
3 Demonstrate ability to find out applications of NLPP in industries and management
4 Acquainted with the use software for the solution of NLPP
5 Acquired knowledge about the formulation techniques for the problem as NLPP

21STA24C4-Practicals (Based on **21STA24C1 & 21STA24C2)** and will be of duration 3 hours.

Paper Code: 21STA24C4
Paper: Practical's (Econometrics & Inference-II-21STA24C1 & 21STA24C2)

Course Objectives

1 To acquire knowledge about Inference of general Linear Regression in Real Life Problems and to investigate ways to analyse when linear restrictions on Regression Coeficients are given
2 To know how to test hypothesis using sequential, procedures and to obtain ASN and OC functions of SPRT.
3 To obtain Admissible Decision Rules ,Optimal Decision Rules, Bayes Rule, Minimax Rules, Bayes Risk & Minimax Risk
4 To test hypothesis using non parametric procedures for one sample and two samples for location problems
5 To understand appropriate test to detect auto-correlation Heteroscedasticity and multicollinearity

Course Outcomes

1 Ability to test hypothesis using sequential procedures
2 Ability to obtain ASN and OC functions of SPRT, and plot them
3 Ability to find Bayes Rule, Minimax Rule , Admissible Decision Rules Bayes' risk and Minimax Risk
4 Ability to test one sample problem using Sign test, Wilcoxom- Sign Test, K-S test and also to test two samples location problems using K-S two samples test, Wald-wolfowitz test, Mann-Whiteney U test
5 Ability to understand the link between econometric and economic data

The question paper will consist of five questions and the student will be required to attempt any three questions. The question paper will set on the spot jointly by the Internal and External Examiner.

Distribution of marks will be as follows: -

Marks for Question Paper	:	36
Marks for Practical Record book	:	06
Marks for Viva-Voice	:	08
Total	:	50

Open Elective: 21STA24C1 (Statistical Programming using R-Language)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching Hours: 04 hrs per week

Paper Code: 21STA24C1
Paper: Statistical Programming using R-Language
Course Objectives

1 To provide a basic understanding of R software
2 To understand the statistical methods using R functions
3 To learn the various plotting functions in R graphics
4 To study the regression analysis and simulation applications in R
5 To provide knowledge about R packages

Course Outcomes

1 Able to use advanced statistical software such as R, SPSS, etc for the analysis of complex statistical data coming from the various fields like industry, marketing, finance, agriculture and business
2 Improved the programming skill and working knowledge of available numerical and Statistical software
3 Gained expertise in handling data through R language
4 Achieved knowledge to understand the applications of R programming in statistics
5 Acquainted with R packages

Unit-I

Introduction & Data Handling in R: Introduction to the Statistical Software R, Introduction to R Studio and dynamic documentation. Data Objects in R, Creating Vectors, Creating Matrices, Data Frame, Manipulating Data, Accessing Elements of a Vector or Matrix, Lists, Addition, Multiplication, Subtraction, Transpose, Inverse of Matrices. Functions operated on Data Objects. Merging of two or more Data Frames, Importing Data, Read and Write Files. Boolean Operators. Handling of Missing and Duplicated Cases/ Observations. Writing own Functions.

Unit-II

R-Graphics: Types of Plotting Functions and their Applications. Histogram, Box plot Steam and Leaf Plot, Scatter Plot, Mat plot. Introduction to ggplot. Plot Options; Multiple Plots in a single Graphic Window, Adjusting Graphical Parameters. Looping: For Loop, repeat Loop, while Loop, If command, if else command.

Unit-III

Statistical Method: Univariate and Multivariate Statistics; Mean, Median, Variance, Coveriance, Correlation, Distribution functions in R, Maximum likelihood Estimation using R-funtions. Model fitting, Parametric and Non-Parametric Tests, Chi-square Tests: goodness of fit, Contingency Tables, Nomality Test in R.

Unit-1V

Analysis of Variance (ANOVA): Factor Variables, ANOVA table, Multiple comparisons; Simple and Multiple Linear Regression Analysis, Generalized Linear Model: Logistic and Poisson Regressions, A Simulation Application: Monte Carlo Integration, Random Sampling, Bootstrapping.

Books Suggested:-

1. Rakshit, S (2018). Statistics with R Programming. McGraw Hill Education.

2. Grolemund, G. (2014). Hands on Programming with R. O′Reilly.
3. Vries, A. de and Meys, J. (2012). R for Dummies. John Wiley & Sons.
4. Lander, J.P. (2017). R for Everyone. Addison-Wesley Professional.
5. Srinivasa, K.G., Siddesh, G.M., Shetty, C. and Sowmya, B.J. (2017). Statistical Programming in R. Oxford University Press.
6. Maheta, D. (2017). Statistical Analysis using R Software. Excel Books Private Limited.
7. Braun, W.J. and Murdoch, D.J. (2007). A First Course in Statistical Programming with R. Cambridge University Press.
8. Wickham. H. (2019). Advanced R. Chapman and Hall/CRC.
9. Xie, Y. (2013). Dynamic Documents with R and knitr. Chapman and Hall/CRC.
10. Gandrud, C. (2013). Reproducible Research with R and R Studio. Chapman and Hall/CRC.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.

Open Elective: 21STA24D4 (Official Statistics)

Maximum Marks-80
Internal Assessment Marks—20
Time:-03 Hours
Teaching Hours: 03 hrs per week

Paper Code: 21STA24D4
Paper: Official Statistics
Course Objectives

1 To Understand the Functioning of Official Statistics
2 To Aquainted with Need of Statistical Agencies to any Country and World
3 To Know how Statistical Agencies are Helping in Taking Vital Decision for any Country
4 To Familier with Institutional, Legal and Organisational Bases and Functioning of Official Statistics
5 To Know About the Strucutre of Various Statistical Agencies around the World and the Methods Used by these Agencies to Collect and Interpret Data and Limitations that Arise during this Process

Course Outcomes

1 Gained Knowledge About the Functioning of Various Statistical Agencies
2 Aquatined with the Knowledge of Structures, Data Collection Methods of Major Statistical Agencies
3 Trained in Methods Used by Agencies and Methods to Overcome the Obstacles in this Process
4 Gained Knowledge About the Different Official Statistical Publications of World and India
5 Acquainted with the Knowledge and Needs of the Various Statistical Agencies around the World and their Importance

Unit-I

Introduction to Indian System, present Official Statistical System in India, Need, Role, Functions and Activates of Central and State Organization, Organization of Large Scale Sample Survey, Methods of Collection of Official Statistics, their Reliability and limitations. Various agencies responsible for the Data Collection CSO, NSSO, NSC, Office of Registrar General, their structure, Data Collection Methods, Limitation and Dissimination.

Unit-II

Introduction to International Statistical System, Comparison of Major Macro Variables, National Income/ GDP, Purchasing Power Parity: Needs, Methods of Calculation, Usages, Reliability, Draw Backs; Indicators relating to energy, environment, gender, industry, National accounts, social statistics and trade.

Unit-III

Sector wise Statistics: Agriculture, Health, Education, Women and Child etc. Surveys and Census by NSSO, Labour Bureau, RBI etc. Indicators, Agencies and usage and Principle publications containing such Statistics, National Family Health Survey.

Unit-IV

Census: Needs, Types of Census Population Census, Types of Population Census, methods of Conditions its Objectives, Essential Features, Utility of Census, different publications of Data of Population Census. Merits and Demerits. Agricultural Census: its objectives, methods of collection,

agricultural data, its features, utility of Census, Merit and Demerits of Agricultural Census, Principal, Publications of Agricultural Data.

Books Suggested:-

1. Saluja, M.R. (1972). Indian Official Statistical Systems, Statistical Pub. Society
2. Saluja, M.R. (2017). Measuring India: The Nation's Statistical System, OUP India
3. Statistical System in India, CSO (MOSPI) Publication
4. Handbook of Statistics for the Indian Economy, RBI (various years)
5. Economic Surveys, Govt. of India, Ministry of Finance (various years)
6. Guide to Current Indian Official Statistics C.S.O., Govt. of New Delhi
7. Office of Registrar General and Census Commissioner India (Ministry of Home Affairs)
8. Basic Statistics relating to the Indian Economy (CSO) 1990.
9. Guide to official Statistics (CSO) 1999.
10. Principles and accommodation of National Populations Census UNESCO.

Note: The examiner is to set nine (09) questions in all into five sections A,B,C,D and E of the question paper from all the four units- I, II, III and IV. In each section A,B,C and D, there will be two questions of 16 marks each from Units I, II, III, & IV respectively. In section E, there will be a compulsory question of marks 16 consisting of 08 short answer type questions (each of marks 02), two from each unit I,II,III and IV. The candidate will be required to attempt five questions in all selecting at least one question from each section.