# University of Kalyani

## Department of Statistics


**STRUCTURE AND DETAILED SYLLABUS FOR**

# 5-Year Integrated M. Sc. Course in Statistics

**With Effect From 2017-18**

# COURSE STRUCTURE

5-Year Integrated M. Sc. in Statistics: SEMESTER 1

| Paper Code | Paper Name | Weekly Contact Period | | | Credit | Marks | | Exam duration | Total marks |
|---|---|---|---|---|---|---|---|---|---|
| | | Th. | Pr. | Total | | Internal Assessment | End-semester Exam | | |
| 5STAT101 | Calculus I | 4 | - | 4 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT102 | Classical Algebra & Determinants | 4 | - | 4 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT103 | Probability I | 6 | - | 6 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT104 | Descriptive Statistics I | 3 | 3 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| Total | | 17 | 3 | 20 | 16 | 80 | 320 | | 400 |

5-Year Integrated M. Sc. in Statistics: SEMESTER 2

| Paper Code | Paper Name | Weekly Contact Period | | | Credit | Marks | | Exam duration | Total marks |
|---|---|---|---|---|---|---|---|---|---|
| | | Th. | Pr. | Total | | Internal Assessment | End-semester Exam | | |
| 5STAT201 | Calculus II | 4 | - | 4 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT202 | Abstract Algebra & Linear Algebra | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| 5STAT203 | Probability II | 4 | - | 4 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT204 | Descriptive Statistics II | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| Total | | 16 | 4 | 20 | 16 | 80 | 320 | | 400 |

5-Year Integrated M. Sc. in Statistics: SEMESTER 3

| Paper Code | Paper Name | Weekly Contact Period | | | Credit | Marks | | Exam duration | Total marks |
|---|---|---|---|---|---|---|---|---|---|
| | | Th. | Pr. | Total | | Internal Assessment | End-semester Exam | | |
| 5STAT301 | Calculus III | 4 | - | 4 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT302 | Computer Basics | 4 | - | 4 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT303 | Multivariate Analysis | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| 5STAT304 | Numerical Analysis | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| Total | | 16 | 4 | 20 | 16 | 80 | 320 | | 400 |

5-Year Integrated M. Sc. in Statistics: SEMESTER 4

| Paper Code | Paper Name | Weekly Contact Period | | | Credit | Marks | | Exam duration | Total marks |
|---|---|---|---|---|---|---|---|---|---|
| | | Th. | Pr. | Total | | Internal Assessment | End-semester Exam | | |
| 5STAT401 | Computer Programming | 3 | 3 | 6 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT402 | Sampling Distribution | 4 | - | 4 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT403 | Parametric Estimation | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| 5STAT404 | Testing of Hypothesis | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| Total | | 15 | 7 | 22 | 16 | 80 | 320 | | 400 |

5-Year Integrated M. Sc. in Statistics: SEMESTER 5

| Paper Code | Paper Name | Weekly Contact Period | | | Credit | Marks | | Exam duration | Total marks |
|---|---|---|---|---|---|---|---|---|---|
| | | Th. | Pr. | Total | | Internal Assessment | End-semester Exam | | |
| 5STAT501 | Economic Statistics & Statistical System | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| 5STAT502 | Demography & SQC | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| 5STAT503 | Linear Programming & Game Theory | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| 5STAT504 | Sampling Techniques | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| Total | | 16 | 8 | 24 | 16 | 80 | 320 | | 400 |

5-Year Integrated M. Sc. in Statistics: SEMESTER 6

| Paper Code | Paper Name | Weekly Contact Period | | | Credit | Marks | | Exam duration | Total marks |
|---|---|---|---|---|---|---|---|---|---|
| | | Th. | Pr. | Total | | Internal Assessment | End-semester Exam | | |
| 5STAT601 | Analysis of Variance | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| 5STAT602 | Design of Experiments | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| 5STAT603 | Large Sample Theory, Sequential Analysis & Nonparametric Inference | 4 | 2 | 6 | 4 | 20 | 80 | 4 hr | 100 |
| 5STAT604 | C-Programming, MINITAB & MS-EXCEL | 2 | 4 | 6 | 4 | 20 | 80 | Assignment | 100 |
| Total | | 16 | 8 | 24 | 16 | 80 | 320 | | 400 |

5-Year Integrated M. Sc. in Statistics: SEMESTER 7

| Paper Code | Paper Name | Weekly Contact Period | | | Credit | Marks | | Exam duration | Total marks |
|---|---|---|---|---|---|---|---|---|---|
| | | Th. | Pr. | Total | | Internal Assessment | End-semester Exam | | |
| 5STAT701 | Real Analysis | 4 | - | 4 | 3 | 12 | 48 | 2 hr | 60 |
| 5STAT702 | Linear Algebra | 2 | 2 | 4 | 2 | 12 | 48 | 2 hr 30 min | 60 |
| 5STAT703 | Sampling Distribution | 4 | - | 4 | 2 | 12 | 48 | 2 hr | 60 |
| 5STAT704 | Sample Survey | 2 | 2 | 4 | 3 | 12 | 48 | 2 hr 30 min | 60 |
| 5STAT705 | Linear Models | 2 | 2 | 4 | 2 | 12 | 48 | 2 hr 30 min | 60 |
| 5STAT706 | Operations Research | 2 | 2 | 4 | 2 | 12 | 48 | 2 hr 30 min | 60 |
| 5STAT707 | C++ Programming | - | 4 | 4 | 2 | 8 | 32 | Assignment | 40 |
| Total | | 16 | 12 | 28 | 16 | 80 | 320 | | 400 |

5-Year Integrated M. Sc. in Statistics: SEMESTER 8

| Paper Code | Paper Name | Weekly Contact Period | | | Credit | Marks | | Exam duration | Total marks |
|---|---|---|---|---|---|---|---|---|---|
| | | Th. | Pr. | Total | | Internal Assessment | End-semester Exam | | |
| 5STAT800 (Open) | Basics of Probability & Statistics | 4 | - | 4 | 4 | 20 | 80 | 4 hr | 100 |
| 5STAT801 | Probability & Measure Theory | 3 | - | 3 | 2 | 12 | 48 | 2 hr | 60 |
| 5STAT802 | Stochastic Process | 2 | 1 | 3 | 2 | 8 | 32 | 2 hr | 40 |
| 5STAT803 | Large Sample Theory | 2 | - | 2 | 2 | 8 | 32 | 1 hr 30 min | 40 |
| 5STAT804 | Design of Experiments | 3 | 2 | 5 | 3 | 16 | 64 | 3 hr | 80 |
| 5STAT805 | Econometrics & Time Series Analysis | 3 | 2 | 5 | 3 | 16 | 64 | 3 hr | 80 |
| Total | | 17 | 5 | 22 | 16 | 80 | 320 | | 400 |

5-Year M. Sc. in Statistics: SEMESTER 9

| Paper Code | Paper Name | Weekly Contact Period | | | Credit | Marks | | Exam duration | Total marks |
|---|---|---|---|---|---|---|---|---|---|
| | | Th. | Pr. | Total | | Internal Assessment | End-semester Exam | | |
| 5STAT901 | Estimation Theory | 3 | 2 | 5 | 3 | 14 | 56 | 2 hr 30 min | 70 |
| 5STAT902 | Testing of Hypothesis | 3 | 2 | 5 | 3 | 14 | 56 | 2 hr 30 min | 70 |
| 5STAT903 | Nonparametric Methods | 3 | 2 | 5 | 3 | 14 | 56 | 2 hr 30 min | 70 |
| 5STAT904 | Decision Theory | 3 | 2 | 5 | 3 | 14 | 56 | 2 hr 30 min | 70 |
| 5STAT905 | SQC and Reliability | 2 | 2 | 4 | 2 | 14 | 56 | 2 hr 30 min | 70 |
| 5STAT906 | R Programming | - | 4 | 4 | 2 | 10 | 40 | Assignment | 50 |
| Total | | 14 | 14 | 28 | 16 | 80 | 320 | | 400 |

5-Year Integrated M. Sc. in Statistics: SEMESTER 10

| Paper Code | Paper Name | Weekly Contact Period | | | Credit | Marks | | Exam duration | Total marks |
|---|---|---|---|---|---|---|---|---|---|
| | | Th. | Pr. | Total | | Internal Assessment | End-semester Exam | | |
| 5STAT1001 | Special Paper | 4 | 2 | 6 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT1002 | Special Paper | 4 | 2 | 6 | 4 | 20 | 80 | 3 hr 30 min | 100 |
| 5STAT1003 | Project | | | | 8 | 40 | Dissertation & Presentation: 160 | | 200 |
| Total | | 8 | 4 | 12 | 16 | 80 | 320 | | 400 |

## DETAILED SYLLABUS

| | | |
|---|---|---|
| **5STAT101** | **Calculus I (Marks 100, Credit 4)** | **45** |
| | Real sequences: Limit points of a sequence, convergent sequences, divergent sequences, monotonic sequences, algebra of convergent sequences, limit superior and limit inferior, Cauchy sequences. | 15 |
| | Series of real numbers: Convergence of a series, positive term series. Alternating series: conditional and absolute convergence, rearrangement of series. Test of absolute convergence: comparison test, Cauchy's root test, D'Alembert's ratio test, Cauchy's integral test. Power series. | 10 |
| | Functions of one variable: limit, continuity, algebra on limits and of continuous functions. Continuity of composite functions. Properties of continuous functions on closed intervals. Uniform continuity. | 10 |
| | Derivative: differential, chain rule, meaning of the sign of a derivative at a point, Rolle's theorem, Mean value theorems with Lagrange and Cauchy, Taylor's theorem with Lagrange's and Cauchy's form of remainder [Maclaurin's series, expansions of cos(x), sin(x), $e^x$, $(1+x)^m$ and log (1+x)], Local maxima and minima. | 10 |

***References:***


1. Das, B.C. and Mukherjee, B.N.: Differential Calculus.
2. Goldberge, R.R (1970): Methods of Real Analysis. Oxford & IBH Publishing Co.
3. Malik, S.C. and Arora, S. (2008): Mathematical Analysis, New Age International (P) Ltd.

**5STAT102 Classical Algebra and Determinants (Marks 100, Credit 4)** **65**

**Classical Algebra**

Algebra of complex numbers: Argand plane, Modulus and argument of complex numbers, properties of moduli and amplitudes of complex numbers. Principal value of arguments, complex conjugate, Imaginary cube roots of unity. De Moivre's theorem (for rational index) and its applications, Exponential, sine, cosine, logarithmic inverse circular and hyperbolic functions of a complex variable. 10

Polynomials: Division algorithm (without proof), Remainder theorem, synthetic division, Application of Remainder theorem, Fundamental theorem of classical algebra (without proof) and its consequences, Multiple roots. Statement and application of Descartes rule of signs. Relation between roots and coefficients, symmetric functions of roots, Transformations of polynomial equations, Cardan's solution of the cubic equation. 20

Some standard algebraic inequalities. 10

**Determinants**

General definition and properties of a determinant, Minors and cofactors. Evaluation of different types of determinant by reducing to a similar form, Adjugate determinant, $r^{th}$ order minor and its algebraic complement. Laplace Development of a determinant, Product theorem, Jacobi's theorem, symmetric and skew symmetric determinants. 25

***References:***


1. Das and Basu: Algebra.
1. Mapa, S.K. : Higher Algebra (Classical).
2. Das & Mukherjee: Higher Algebra.
3. Ferrar.
4. Searle.


**5STAT103 Probability I (Marks 100, Credit 4 )** **65**

Random Experiment, Sample point, Sample space, Event, classical 20

definition of probability and limitations, statistical regularity and meaning of probability, probability by relative frequency, related exercises.

Operation on events, field of events, Kolmogorov's axiomatic definition of probability, detailed discussion on discrete space only. 10

Results on probability on union and intersection of events, conditional probability, independence, Bayes' theorem and its applications. Related exercises, Geometric probability. 20

Random variable, cumulative distribution function (c.d.f.) of a random variable and its properties, p.m.f. and p.d.f., expectation, variance, moments, quantiles, p.g.f., Chebyshev's inequality. 15

***References:***


1. Feller W. (1968): An Introduction to probability Theory & its Applications, John Willy.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B: Fundamentals of Statistics, Vol. 1- World Press.
3. Rohatgi, V.K. (1984): An Intro to Prob. Theory and Mathematical Statistics, John Wiley.
4. Hoel, P.J., Port, S.C. & Stone, C.J.: Introduction of Probability Theory (Vol-I) Houghton Mifflin & UBS.
5. Prazen, E. (1972): Modern Probability Theory and its Applications, John Wiley.
6. Uspensky, J.V. (1937): Introduction to Mathematical Probability, McGraw Hill.
7. Cacoullos, T. (1973): Exercise in Probability, Narosa.
8. Pitman, J. (1993): Probability, Narosa.
9. Chandra, T. K. & Chatterjee, D. (2001): A First Course in Probability, Narosa.
10. Mukhopadhyay, P. (1996): Mathematical Statistics.
11. Mukhopadhyay, P.: Theory of Probability.
12. Wilks, S.S. (1962): Mathematical Statistics, Wiley.
13. Bhat, B.R.: Modern Probability Theory.


**5STAT104 Descriptive Statistics I (Marks 100, Credit 4) 45**

Type of data: Basic concept, individual, population, sample, qualitative and quantitative data, nominal and ordinal data, cross 4

sectional and time series data, discrete and continuous data, frequency and non-frequency data.

Collection and Scrutiny of Data: Primary and secondary data, method of collection, scrutiny of data for internal consistency and detection or errors. 3

Presentation of data: Compilation, tabulation, diagrammatic representation, frequency distribution, stem-and leaf displays, column or bar diagram, pie-diagram, divided bar diagram, histogram, frequency polygon and ogives, Box plot. 8

Descriptive measure or univariate quantitative data: Measure of location, dispersion, relative dispersion, moments qualities, skewness and kurtosis, statement of Sheppard's correction for moments, moment inequalities, Various problems related to location, dispersion, skewness and kurtosis, Gini's coefficient and Lorenz curves . 30

***References:***


1. Goon, A.M., Gupta, M.K. & Dasgupta, B. Fundamentals of Statistics, Vol. 1, World Press, Kolkata.
2. Agresti, A. (1996): An Introduction to Categorical data analysis, John Wiley & Sons.
3. Yule, G.U. & Kendall, M.G. : An Introduction to the Theory of Statistics.
4. Kendall, M.G. & Stuart, A: Advanced Theory of Statistics Vol.1.


**5STAT201 Calculus II (Marks 100, Credit 4 ) 45**

Indefinite integral as a reverse process of differentiation, evaluation of some standard indefinite integrals, Reimann's definition and existence of the integral, elementary properties. Integrability of continuous functions. The fundamental theorem of integral calculus. Reduction formulae for 15

$\int_0^{\pi/2} \sin^n x\,dx, \int_0^{\pi/2} \cos^n x\,dx, \int_0^{\pi/2} \sin^n x \cos^m x\,dx, \int_0^{\pi/2} \tan^n x\,dx$

Improper integrals: Notions of improper integrals. Beta and Gamma 10

functions (convergence assumed), their mutual relations and elementary properties.

Sequence and series of functions: pointwise convergence, uniform convergence and absolute convergence, simple tests of convergence. 10

Evaluation of simple plane areas, are lengths, volumes and surfaces of solids of revolution. 10

***References:***


1. Das, B.C. and Mukherjee, B.N.: Differential Calculus.
2. Goldberge, R.R (1970): Methods of Real Analysis. Oxford & IBH Publishing Co.
3. Malik, S.C. and Arora, S. (2008): Mathematical Analysis, New Age International (P) Ltd.


**5STAT202 Abstract and Liner Algebra (Marks 100, Credit 4 ) 75**

**Abstract Algebra**: Sets, Finite and infinite sets, subsets and power sets of a set, Equality, Union, intersection, complement, difference and symmetric difference of sets. Basic laws for union and intersection of sets. De Morgan's law. Ordered pair Cartesian product of two sets. 6

Binary relation in a set, equivalent relation, partition, injective, surjective and bijective mapping, identity mapping, inverse of a mapping, composition of mappings. 4

Groups, semi-groups, Abelian and non-Abelian group, examples, identities in groups, $a^m a^n = a^{m+n}$ and $(a^m)^n = a^{mn}$ , where m & n are integers. Uniqueness of identity and inverse of an element in a group, solutions of ax=b and ya=b in a group, Cancellation laws. Subgroups and their characterization, Invariance of identity and inverse of an element in subgroups. Finite groups, composition table, order of a group, order of an element in a group, Notion of Cyclic groups. 8

Definition and examples of rings, Zero divisions, integral domains and fields. 12

**Linear Algebra:** Vectors: Finite dimensional vector space over a field of real numbers, addition and scalar multiplication of vectors, linear combination and linear independence, basis dimension, subspace, union, intersection, sum and direct sum of subspaces: related results and examples. Norm of a vector. Inner product, Euclidean space, orthogonality and Gram –Schmidt process. 22

Matrices: Definition, Various types of matrices, matrix operation, Elementary matrices, row space, column space, Elementary operation, rank of a matrix and related results. Transpose of matrix, symmetric matrix. Determinant of a square matrix, inverse of a matrix, orthogonal matrix. Partitioned matrix and its inverse, reduction of a matrix to a normal form. Echelon form. 23

Homogeneous and non-homogeneous system of linear equations, nullity, consistency, related results.

Characteristics equation of matrix, eigenvalues and eigenvectors, simple related results regarding real symmetric matrices.

Quadratic forms: Classification, Canonical reduction, spectral decomposition.

***References:***


1. Ray, K.C. and Das, A.G. – Abstract and Linear Algebra.
2. Lahiri, B.K. & Ray, K.C. – Higher Algebra.
3. Shanti Narayan: A Text Book of Matrices, S. Chand.
4. Hadley. G: Linear Algebra.
5. Lipschutz, S.: Theory & Problems of Linear Algebra, Schaum's Outline Series.
6. Chatterjee, B.C.: Abstract Algebra, Vol-II.
7. Chatterjee, B.C.: Linear Algebra.
8. Rao and Bhimasankaram.
9. Chakraborty and Ghosh.
10. Honn.

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|---|---|---|
| **5STAT203** | **Probability II (Marks 100, Credit 4)** | **45** |
| | Standard univariate discrete distributions: degenerate, discrete uniform, Bernoulli, Binomial, hypergeometric, Poisson, geometric, negative binomial with their properties, related exercises. | 15 |
| | Standard univariate continuous distributions: rectangular, normal, Cauchy, gamma, beta, exponential, lognormal distributions and their properties. | 15 |
| | Bivariate probability distributions, marginal and conditional distributions, covariance, correlation coefficient, conditional expectation and variance, bivariate normal distribution and its properties. | 15 |

***References:***


1. Feller W. (1968); An Introduction to probability Theory & its Applications, John Willy.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B: Fundamentals of Statistics, Vol. 1- World Press.
3. Rohatgi, V.K. (1984): An Introduction to Probability Theory and Mathematical Statistics, John Wiley.
4. Hoel, P.J., Port, S.C. & Stone, C.J.: Introduction of Probability Theory (Vol-I) Houghton Mifflin & UBS.
5. Prazen, E. (1972): Modern Probability Theory and its Applications, John Wiley.
6. Uspensky, J.V. (1937): Introduction to Mathematical Probability, McGraw Hill.
7. Cacoullos, T. (1973): Exercise in Probability, Narosa.
8. Pitman, J. (1993): Probability, Narosa.
9. Chandra, T. K. & Chatterjee, D. (2001): A First Course in Probability, Narosa.
10. Mukhopadhyay, P. (1996): Mathematical Statistics.
11. Mukhopadhyay, P: Theory of Probability.

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|---|---|---|
| **5STAT204** | **Descriptive Statistics II (Marks 100, Credit 4)** | **65** |
| | Measures on bivariate quantitative data: Scatter diagram, Product-moment Correlation Coefficient-its properties, intra-class correlation coefficient with equal and unequal group sizes, concept of regression, principle of least squares regression curves and related results, Correlation index, Correlation ratio and related inequalities, Rank Correlation – Sperman's and Kendall's measures including tie cases. | 35 |
| | Categorical Data Analysis: Consistency of Categorical data, independence and association of attributes, Various measures of association for two way classified data, odds ratio. | 10 |
| | Scaling of Data: Motivation of scaling, types of scales- nominal, ordinal, ratio and interval scales. Measurement of psychological traits, scaling of items according to difficulty. Scaling of test scores, scaling of rates and ranks, scaling of judgements. | 15 |
| | Fitting of binomial, Poisson and normal distributions | 5 |

***References:***

All reference related to **5STAT104** followed by


1. Agresti, A. (1984): Analysis of Ordinal Categorical Data.
2. Guilford, J.P. and Frucheter, B (1980) : Fundamental Statistics in Psychology and Education, Mc Graw Hill.
3. Mukhopadhyay, P: Applied Statistics, Books and Allied (P) Ltd., Kolkata.
4. Goon, A.M. Gupta, M.K. & Dasgupta, B: Fundamentals of Statistics, Vol 2, Seventh Edition, World Press, Kolkata.


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|---|---|---|
| **5STAT301** | **Calculus III (Marks 100, Credit 4)** | **40** |
| | Functions of several variables: Notions of partial derivatives of implicit functions, chain rules, total differential and derivatives of implicit functions. Simple counter example to $f_{xy} = f_{yx}$. Schwarz's theorem on the equality (Statement only), Euler's theorem on homogeneous functions of two variables (problems up to three variables). Lagrange's method of multipliers for extreme (working | 12 |

rules only).

| | |
|---|---|
| Multiple integrals, transformations and Jacobians (Statement and examples), polar and orthogonal transformations, Dirichlet's integral. | 13 |
| Differential equations: Genesis of ordinary differential equations. First order linear and non-linear equations. Exact equations, use of integrating factors, First order and higher degree equations. Clairaut's form, singular solution. Second and higher order linear equations with constant coefficients. Euler's homogeneous equations. Simultaneous linear equations of first and second order. | 15 |

***References:***


1. Das, B.C. and Mukherjee, B.N. : Differential Calculus.
2. Goldberge, R.R (1970): Methods of Real Analysis. Oxford & IBH Publishing Co.
3. Goldberge, R.R. (1970): Methods of Real Analysis. Oxford & IBH Publishing Co.
4. Malik, S.C. and Arora, S (2008): Mathematical Analysis, New Age International (P) Ltd.
5. Shanti Narayan and Mittal, P.K. (2004): A course of Mathematical Analysis. S. Chand & Co. Ltd.


**5STAT302 Computer Basics (Marks 100, Credit 4) 50**

| | |
|---|---|
| Brief history of evolution of computers. | 3 |
| Classification of Computers: Special purpose and general purpose, analog, digital and hybrid, super, main-frame, PC etc, Organization of general purpose digital computers, CPU, main memory and peripherals, Mass storage devices and other I/O devices. | 3 |
| Computer languages: Machine language, assembly language and higher level languages | 3 |
| Software: OS, linker, loader, compiler, interpreter and assembler. | 4 |
| Object oriented programming languages: Basic characteristics, brief comparison with other types of languages. | 3 |
| Elements of Boolean algebra: Concepts of AND, DR, NAND, NOR, XOR and their applications. Truth tables. | 8 |
| Computer arithmetic and ALU: Number systems – binary, octal, | 10 |

| | | |
|---|---|---|
| | decimal and hexadecimal. Uses in arithmetic. | |
| | Memory, memory devices, static and dynamic, RAM, ROM, cache and secondary memory devices. | 9 |
| | Introduction to Database Management System: Database system, Advantage of Database system, Database users, Database languages, Data model, Database schema and instance, Relational data model in brief. | 7 |

***References:***


1. Sinha & Sinha: Computer Fundamentals.
2. Andersen, R.: Computer studies: A First Year Course.
3. Sloan, M.E.: Introduction to Minicomputer and Microcomputer.


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| **5STAT303** | **Multivariate Analysis (Marks 100, Credit 4)** | **50** |
| | Multivariate Probability Distribution: Mean vector and covariance matrix, marginal and conditional distribution, ellipsoid of concentration, multiple regression, multiple correlation, partial correlation. | 15 |
| | Standard Multivariate Probability Distributions: Multivariate normal, multinomial, Dirichlet distributions, their properties and related results. | 15 |
| | Descriptive measures on multivariate data: multiple correlation, partial correlation, relationship between higher order and lower order partial correlations, related problems and inequalities. | 20 |

***References:***


1. Anderson, T.W.: An Introduction to Multivariate Analysis (Chapter-2), John Wiley.
2. Gun, A.M. Gupta, M.K. & Dasgupta, B.: Fundamentals of Statistics, Vol-1 (Chapter-II), World Press, 2002.
3. Kendall, M.G. & Stuart, A: Advanced Theory of Statistics, Vol 1 (Ch. 15), Vol (Ch-26, 27), Charles Griffin.
4. Gun, A.M. Gupta, M.K. & Dasgupta, B.: an outline of Statistical Theory, Vol-1, World Press, 2003.

5. Rao, C.R.: Linear Statistical Theory and its Applications (Chapter-4 &8), Wiley Eastern, 1974.
6. Wilks, S.S.: Mathematical Statistics (Chapter 6 & &) John Wiley.

**5STAT304 Numerical Analysis (Marks 100, Credit 4) 40**

| | |
|---|---|
| Approximation of number and functions, Absolute and relative errors, Δ & E operators, related problems on separation of symbols. | 5 |
| Interpolation Formulae: Newton's forward, Newton's backward, Lagrange's formulae. | 6 |
| Divided Difference operator, Newton's divided difference formula. Central interpolation formulae by Stirling and Bessel. | 8 |
| Subtabulation, Inverse interpolation. | 3 |
| Numerical differentiation and its applications. | 2 |
| Numerical Integration: Quadrature formula. Trapezoidal, Simpons' 1/3 rd and $3/8^{th}$ rules with error terms. | 8 |
| Numerical solution of equation in one unknown. Regula-falsi, bisection, iterative, Newton-Raphson methods. Condition of convergence. | 8 |

***References:***

1. Scaborough, J.B.: Numerical Analysis.
2. Jain, M.K. Iyenger, S. R. K. & Jain, R. K.: Numerical Methods for Scientific and Engineering Computation, New age International.
3. Saxena, H.C.: The Calculus of Finite Differences, S.Chand & Com., New Delhi.
4. Goon, A.M., Gupta, M.K. & Dasgupta, B,: Fundamentals of Statistics, Vol-1- World Press, Kolkata.
5. Freeman, H (1962): Finite Differences for Actuarial Students, Cambridge University Press.
6. Kalyan Mukherjee: Numerical Analysis.

**5STAT401 Computer Programming (Marks 100, Credit 4) 50**

| | |
|---|---|
| Algorithm and Flowchart. Algorithm and Flowchart for specific examples – Fibonacci numbers, prime numbers, linear search, insertion sort, bubble sort. | 4 |
| Storage of information: Concepts of records and files, file | 2 |

organization: sequential, relative and indexed.

**Programming with FORTRAN** 4

Introduction to FORTRAN 90 or 95, FORTRAN character codes, constants, variables, names, Operators- arithmetic, logical and relational operators.

Arithmetic expressions: Arithmetic, character, relation and logical expressions. Rules for writing arithmetic expressions, Type conversion in statements, Mixed mode operations, intrinsic functions. 6

Statements: Input/output statements, Assignment statements, Arithmetic statements, conditional statements: IF-THEN-ELSE control statements, DO loops, Do-Continue, CASE statement, GO TO (unconditional, conditional, computed) statement. 12

Format Specification: Format description for read statement and print statement, Multi record formats: Record spacing and tabulation, Printing Character strings, Generalized input/output statements. 6

Arrays: One-dimensional, two-dimensional, multidimensional, handling array using DO loop, Array initialization, terminologies of array, matrix manipulation using array. 8

Subprograms: Subroutine subprograms and Function subprograms, external functions, generic functions, Subroutines. 8

**Practical**

FORTRAN program for:

1. Factorial of a positive integer
2. Ordering of a given set of observations
3. Finding maximum and minimum of a given set of observations
4. Mean, variance and quantiles for grouped and ungrouped data.
5. Correlation coefficient for ungrouped data
6. Fitting of binomial and Poisson distributions

7. Calculating correlation coefficient for grouped data.

***References:***


1. Rajaraman, V.: Computer programming in FORTRAN 90
2. Lipschutz & Poe.


| | | |
|---|---|---|
| **5STAT402** | **Sampling Distribution (Marks 100, Credit 4)** | **50** |
| | Concept of random sampling, statistic and sampling distribution of statistics. Different methods for finding sampling distribution of a statistic. Derivation of the distribution of the sample total related to binomial and Poisson populations and conditional distribution of single observation given the total. | 8 |
| | Distribution of the sum of two i.i.d. rectangular variables and sum & ratio of the two independent gamma variables and sum of two independent beta variables. | 5 |
| | Distribution of linear function of independent normal variables, ratio of two independent normal variables, central $\chi 2$, t & F distributions. Definitions of non-central $\chi 2$ , t and F. | 14 |
| | Sampling distributions of mean and variance of a random sample from a normal population. | 3 |
| | Sampling distributions of means, variance and correlation coefficient of a random sample from a bivariate normal population. Distribution of sample regression coefficient for both stochastic and non-stochastic regressors. | 10 |
| | Distribution of sample order statistic from a continuous population, distribution of sample range and quantiles. | 10 |

***References:***


1. Hogg, R.V. & Craig, A.T. (1978): Introduction to Mathematical Statistical, Collier, Macmillan Pub.

2. Goon, A.M., Gupta, M.K. & Dasgupta, : An Outline of Statistical Theory, Vol. 2, World Press, Kolkata.
3. Rao, C.R.: Linear Statistical Inference and its application, Wiley Eastern.
4. Rohatgi, V.K. (1986): An introduction of Probability Theory and Mathematical Statistics, Wiley Eastern.
5. Mukhopadhyay, P.: Mathematical Statistics.
6. David and Nadaraja: Order Statistics.
7.

**5STAT403 Parametric Estimation (Marks 100, Credit 4)** **40**

Data reduction: Sufficiency, factorization theorem (Proof in discrete case only) 5

Point estimation: Properties of estimators, mean square error (MSE) and minimum MSE estimator, unbiasedness and minimum variance unbiased estimators (MUUE), Rao-Cramer lower bound and related results, Rao-Blackwell theorem, relative efficiency of an estimator, Fisher's information. 15

Consistency, notion of asymptotic efficiency Methods of estimation: method of moments, method of maximum likelihood (excluding proofs of large sample properties), method of minimum chi-square, method of least-squares. 12

Basic concepts of Bayes' estimation: prior and posterior distributions, posterior mean as an estimator of the parameter, application to simple examples on Bernoulli and normal populations. 8

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Statistical hypotheses- Simple and composite, two types of errors, level of significance, p-value, size of a test, power of a test, unbiased tests. Most powerful (MP), uniformly Most Powerful (UMP) and Uniformly Most Powerful unbiased (UMPU) tests, Randomized and non-randomized tests, Fundamental Neyman-Pearson (NP) Lemma (Proof of sufficiency part only) and its use in the construction of MP and UMP test (single parameter with range independent of

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| | parameter), Power curve. | |
| | Exact test of significance relating to binomial, Poisson and normal parameters. | 5 |
| | Likelihood Ratio (LR) tests, its applications in connection with univariate normal and for the equality of means and variances of several univariate normal populations. | 8 |
| | Interval estimation: Confidence intervals and confidence sets, confidence coefficient, confidence, intervals for the parameters of univariate normal, difference of means of two independent homoscaedastic normal distributions. | 8 |

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| **5STAT404** | **Testing of Hypothesis (Marks 100, Credit 4)** | **40** |
| | Simple and composite, two types of errors, level of significance, p-value, size of a test, power of a test, unbiased tests. Most powerful (MP), uniformly Most Powerful (UMP) and Uniformly Most Powerful unbiased (UMPU) tests, Randomized and non-randomized tests, Fundamental Neyman-Pearson (NP) Lemma (Proof of sufficiency part only) and its use in the construction of MP and UMP test (single parameter with range independent of parameter), Power curve. | 16 |
| | Exact test of significance relating to binomial, Poisson and normal parameters. | 8 |
| | Likelihood Ratio (LR) tests, its applications in connection with univariate normal and for the equality of means and variances of several univariate normal populations. | 8 |
| | Interval estimation: Confidence intervals and confidence sets, confidence coefficient, confidence, intervals for the parameters of univariate normal, difference of means of two independent homoscaedastic normal distributions. | 8 |

***References:***

1. Goon, Gupta and Dasgupta: An Outline of Statistical Theory, Vol.2 .

2. Rohatgi, V. K. & Saleh, A.K.M.E.: An Introduction to Probability Theory and Mathematical Statistics, 2nd Ed.
3. Mukhopadhyay, P.: Mathematical Statistics.
4. Santhakumaran, A.: Fundamentals of Testing Statistical Hypotheses.
5. Rao, C.R.: Linear Statistical Inferences and its Applications.
6. Kale, B. K.: Parametric Inference
7. Hogg and Craig: Introduction to Mathematical Statistics,
8. Mood, A. M., Graybill, F. A. and Boes, D. C. (1974): Introduction to the Theory of Statistics, McGraw Hill and Kogakusha.

**5STAT501 Economic Statistics and Indian Statistical System (Marks 100, Credit 4)** **55**

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| Price, quantity and value indices, Problem of Construction of index numbers: Laspeyre's, Paasches', Edgeworth-Marshal's, Fisher's ideal formulae, chain base index number, Test for index numbers: Time and Factor reversal tests, Circular test. | 10 |
| Some important indices: consumer price index, wholesale price index-methods of construction and uses. | 2 |
| Economic time series, different components, additive and multiplicative models, determination of trend, by moving average and mathematical curve fitting, Slutsky-Yule effect, analysis of seasonal fluctuation, construction of seasonal indices. | 11 |
| Stationary Time Series – Weak stationary, definition of Auto Regression (AR), Moving Average (MA) processes; Discrimination between AR(1), AR(2), MA(1) and MA(2) processes by Correlogram analysis. Sample autocorrelation, Estimation of parameters of AR(1) and AR(2) processes. Forecasting: Exponential smoothing and Holt-Winter's method | 12 |
| Theory and analysis of consumer's demand: Law of demand, price elasticity of demand, Engel curve-its different forms and properties. Income elasticity of demand. Estimation of Engel curves from family | 10 |

budget data by Weighted Least Squares method.

The Statistical system in India: The Central and State Government Organizations, functions of the Central Statistical Organization (CSO), the National Sample Survey Organization (NSSO) and West Bengal Bureau of Applied Economic and Statistics (BAES) 10

Sources of official Statistics in India and West Bengal relating to: population, agriculture, industry, trade, price and employment.

Brief ideas of National Income Statistics.

***References:***


1. Goon, A.M., Gupta, M.K. & Dasgupta, B: Fundamentals of Statistics, Vol. II-World Press, Kolkata.
2. Parimal Mukhopadhyay: Applied Statistics.
3. Prais & Houthakker- Analysis of Family Budget Data.
4. Kendall, M.G. & Stuart, A: The Advanced Theory of Statistics, Vol. III.
5. Chatfield, C. (1980): The Analysis of Time Series – An Introduction, Chapman & Hall.
6. Allen, R.G.D.: Index Numbers in Theory and Practice, Mc. Million Press Ltd.
7. Brokwell, P.J. & Davis R.A.: Introduction to Time Series and Forecasting, Springer-Verlag.
8. Saluja, M.P.: Indian Official Systems, Statistical Publishing Society, Kolkata.
9. Goon, A.M., Gupta, M. K. & Dasgupta, B: Fundamentals of Statistics, Vol.2 – World Press, Kolkata
10. Statistical System in India (1984) –C.S.O.


**5STAT502 Demography & SQC (Marks 100, Credit 4)** **70**

Demography:

Sources of demographic data, errors in census and registration data and their adjustment. 3

Measurement of mortality: Crude Death Rate, standardization of death rates, cause of death rate, Infant Mortality Rate, Maternal Mortality Rate: CBR, GFR, Age-specific Birth Rates, TFR, GRR and 15

NRR

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| Complete life table- description, Cohort stable population and stationary population. Notion of abridged life table and construction by Chiang's method. | 15 |
| Measurement of Morbidity. | 2 |
| Graduation of mortality rates by Gompertz and Makeham's laws. Logistic curve and its fitting by Rhodes' method for population forecasting. | 10 |

**SQC**

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| Concepts of quality and quality control, process control and product control. | 5 |
| **Process control:** Charts and their uses, choice of subgroup sizes, construction and interpretation of x-bar, R, s.d., p, np and c charts with fixed and variable subgroup sizes. Modified Control Charts for means. | 8 |
| **Product control:** Acceptance sampling plan, single and double sampling plans by attributes, OC, ASN (and ATI), AOQ curves, LTPD and AOQL Plans for single and double sampling by attributes , single sampling plan for inspection by variables (one-sided specification, known and unknown $\sigma$ cases) | 12 |

***References:***


1. Goon A.M., Gupta, M.K. & Dasgupta, B (2001): Fundamentals of Statistics, Vol. 2- World press, Kolkata.
2. Duncan, A.J.: Quality and Industrial Statistics, 4th edition, Taraporewale & Sons.
3. Montgomery, D.C.: Introduction to the Statistical quality control. 2nd edition John Wiley & Sons.
4 Bhasker D. Misra: An Introduction to the Study of Population, South Asian Publishers Pvt. Ltd., New Delhi.
5 Mukhopadhyay, P. : Applied Statistics, Books and Allied (P) Ltd, Kolkata -9

6 Goon A.M., Gupta, M.K. & Dasgupta, B.: Fundamentals of Statistics, Vol. 2- World press, Kolkata.
7 Biases, S.: Demography.

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| **5STAT503** | **Linear Programming and Game Theory (Marks 100, Credit 4)** | **55** |
| | Linear programming: Introduction, statement and formulation of LPP, graphical solution in simple cases. Preliminary mathematics: separating hyperplane theorem (statement only), Convex sets. | 15 |
| | Slack and surplus variables, feasible solutions, standard form and canonical form, fundamental theorem of linear programming and allied results, simplex method and simplex algorithm, artificial variable technique, two-phase method and method of penalties. | 20 |
| | Game theory: Introduction: 2 person zero-sum games, pure and mixed strategies, existence of solution and uniqueness of value in zero sum games. LP formulation of a 2 person zero sum game and its solution for m x m case. | 20 |

***References:***

1 Gass: Linear Programming.

2. Hadley. Linear Programming.

3. Kambo N.S.: Mathematical Programming Techniques.

4. Goel and Mittal: Operations Research.

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| **5STAT504** | **Sampling Techniques (Marks 100, Credit 4)** | **54** |
| | Introduction: Concepts of a finite population and sample, need for sampling, complete enumeration and sample surveys. | 3 |
| | General ideas: Planning and execution of sample surveys, analysis of data and reporting, Biases and Errors, Judgement and probability sampling. Tables of Random Numbers and their uses. | 7 |
| | Basic sampling and estimation procedures: Simple Random sampling | 30 |

with and without replacement, stratified sampling, linear and circular systematic sampling, cluster sampling. Two stage (with equal sized first stage units) sampling under SRSWOR at each stage. Associated unbiased estimators of population total, mean and proportion, their variances and unbiased variance estimators. Determination of sample size in simple random sampling. Allocation problem in stratified random sampling and optimum choice of sampling and sub-sampling fractions in two-stage sampling.

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| Ratio and Regression method of estimation in simple random sampling. | 5 |
| Double sampling for ratio and regression estimators. PPSWR sampling. | 5 |
| Interpenetrating sub-sampling technique for unbiased variance estimation and its application. | 2 |
| Randomized Response Technique: Warner's model. | 2 |

***References:***


1. Goon. A. M., Gupta, M. K. & Dasgupta, B. (2001): Fundamentals of Statistics, Vol.2, World Press.
2. Murthy, M.N. (1977): Sampling Theory and Methods, Statistical Publishing Society., Calcutta.
3. Des Raj and Chandok, P. (1988): Sample survey theory, Narosa, Publishing House.
4. Cochran, W.G. (1984): Sampling Techniques ($3^{rd}$ Ed.) Wiley Eastern.
5. Mukhopadhyay, P. (1998): Theory and Methods of Survey sampling, Prentice Hall.
6. Sukhatme, P.V., Sukhatme, B.V. and Ashoke, C. (1997): Sampling Theory of Surveys with Applications, Indian Society of Agricultural Statistics.


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| **5STAT601** | **Analysis of Variance (Marks 100, Credit 4)** | **33** |
| | Linear models, Linear parametric function, Methods of least squares, Statement of Fisher-Cochran Theorem. | 10 |

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| | Application of the ANOVA technique to: one-way classified data, two-way classified data with equal number of observations per cell (fixed, random and mixed). | 15 |
| | Testing simple regression coefficients, correlation ratio, simple linear regression and multiple regression analysis. | 8 |

***References:***


1. Scheffe, H. (1959): The Analysis of Variance, John Wiley.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2001): Fundamentals of Statistics, Vol 2, World Press.


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| **5STAT602** | **Design of Experiments (Marks 100, Credit 4)** | **40** |
| | Principles of experimental design: Randomization, Replication and Local Control, Uniformity Trials. | 4 |
| | Standard Designs and their Analyses : Completely Randomized Design (CRD), Randomize Block Design (RBD), Latin Square Design (LSD), Split Plot Design and Strip arrangements, comparison of efficiencies. Application of the techniques of analysis of variance for the analysis of the above designs. | 16 |
| | Group of Experiments using RBD. | 4 |
| | Factorial Experiments: Advantages, $2^n$–experiments, Total and partial confounding, analysis and construction of $3^2$ and $3^3$ designs with confounding. | 12 |
| | Missing Plot Technique: Analysis with one missing plot in RBD and LSD. | 4 |

***References:***


1. Scheffe, H. (1959): The Analysis of Variance, John Wiley.
2. Kempthorne, O. (1965): The Design and Analysis of Experiments, Wiley Eastern.
3. Das, M.N. & Giri, N.C. (1986): Design and Analysis of Experiments, Wiley Eastern.

4. Montgomery, D.C. (1976): Design and Analysis of Experiments, Wiley Eastern.

5. Cochran, W.G. & Cox, G.M. (1957): Experimental Designs, John Wiley.

6. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2001): Fundamentals of Statistics, Vol2-World Press.

7. Mukhopadhyay, P. (1999): Applied Statistics.

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| **5STAT603** | **Large Sample Theory, Sequential Analysis and Nonparametric Inference (Marks 100, Credit 4)** | **60** |
| | **Large Sample Theory**: Notion of convergence in probability and in law, statement of Slutsky's theorem, Chebyshev's WLLN, Central Limit Theorem (CLT), use of CLT for deriving large sample tests for binomial proportions, difference of two binomial proportions, mean of a population and difference of means of two independent populations. Related confidence intervals. | 12 |
| | Large sample standard error; derivation of large sample standard error of a function of statistics in the multiparameter situation, sample moments, standard deviation, coefficient of variation, $b_1$ and $b_2$ measures and correlation coefficient. Uses of these standard errors in large sample tests and interval estimation, test of normality. | 12 |
| | Transformation of statistics to stabilize variance: derivations of $\sin^{-1}$, square-root, logarithmic and z-transformation and their uses in large sample tests and interval estimation. | 6 |
| | Derivation of the large sample distribution of Pearsonian $\chi 2$ - statistic and its uses in test of independence, homogeneity and goodness of fit. | 8 |
| | **Sequential Analysis**: Need for sequential inference, Wald's SPRT with illustrations, Determination of boundaries approximately, Expression for OC and ASN functions (without proof) of tests regarding parameters of binomial, Poisson and normal distributions. | 10 |
| | **Nonparametric Inference**: Need for nonparametric inference, sample median and interquartile range as point estimates of location | 12 |

and dispersion, distribution-free interval estimation of population quantile, tolerance interval, sign test, Wilcoxon signed-rank test, Mann-Whitney test, run test, median test and tests based on Kendall's t and Spearman's rank correlation coefficient, test of randomness.

***References:***


1. Cramer, H.: Mathematical Methods of Statistics, Princeton University Press.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B : An Outline of Statistical Theory, Vol. 1, World Press, Kolkata.
3. Goon, A.M., Gupta, M.K. & Dasgupta, B (2001): Fundamentals of Statistics, Vol. 2, World Press.
4. Rao, C.R.: Advanced Statistical Methods for Biometric Research.
5. Rao, C.R.: Linear Statistical Inference and its Applications.
6. Goon, A.M., Gupta, M.K. & Dasgupta, B (2001): Fundamentals of Statistics, Vol. 1, World Press.
7. Rohatgi, V.K.: An Introduction to probability Theory and Mathematical Statistics, John Wiley.
8. Rohatgi, V. K.: Statistical Inference, John Wiley.
9. Gibbons.


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| **5STAT604** | **C-programming, MINITAB and MS-EXCEL (Marks 100, Credit 4 )** | **40** |
| | Programming preliminaries in C: Structure of the language, lexical element of C, programming environment in C, operators and modes of arithmetic expressions.<br>Input-Output in C: Input-output functions and their format specifications, C-control structure: unconditional (GOTO) control, conditional (if else) control, loop control for loop, while loop, do-while loop. | 12 |

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| | C-functions; library functions, user-defined functions, functions declarations. | |
| | Problems by C-programming<br>(i) Numerical integration by trapezoidal & Simpson's $1/3^{rd}$ rule.<br>(ii) Solution of transcendental equations by bisection, iteration and Newton-Raphson method.<br>(iii)Fitting of straight line and exponential curve to given data.<br>(iv)Fitting of binomial and Poisson distributions.<br>(v)Calculation of correlation coefficient from grouped data.<br>(vi)Inverting non-singular matrix (up to order 4).<br>(vii)Simulation from rectangular, binomial, normal, $X^2$, t-distributions. | 8 |
| | Use of MINITAB using the option under, 'CALCULATION' and 'STATISTICS'<br>Some suggested problems:<br>(i)Basic statistics-Display, descriptive measures (univariate), one sample Z and t-test, two sample and paired t tests for proportion, test for one and two variances and correlations.<br>(ii)Regression: Linear & Multiple regression – fitted and residual plots.<br>(iii)ANOVA – one way & two way classified data.<br>(iv)Control charts – Mean, Range, Mean-SD, proportion no. of defectives, number of defects charts. | 12 |
| | 1. MS-Excel<br>(i) Use of spreadsheet.<br>(ii)Drawing of diagrams – bar, columns, pie.<br>(iii)Use of functions: Mathematical, statistical and logical.<br>(iv)Determination of trend by moving averages and curve fitting methods, plotting fitted values.<br>(v) Exponential smoothing of a time series. | 8 |

***References:***


1. Balagurusamy: Programming in ANSI C, 3rd Ed.
2. Gottfried: Programming with C.
3. Kernighan and Ritchie: The C Programming Language.
4. Ryan, B. and Joiner, B.L. MINITAB Handbook, 4th Ed.


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| **5STAT1701** | **Real Analysis (Marks 60, Credit 3)** | **44** |
| | Introduction to real number, cluster points of sets, closed and open sets, compact sets, Bolzano-Weierstrass theorem, Heine-Borel theorem. | 15 |
| | Sequence and series, Convergence. Real valued functions. Limit, continuity and uniform continuity, Differentiability of univariate and multivariate functions. Mean value Theorems, Extreme of functions. | 15 |
| | Riemann Integral. Improper integrals. Riemann – Stieltjes integral. | 12 |
| | Sequence and series of functions, uniform convergence, Power series. | |
| | Convex functions and related properties | 2 |

***References:***


1. Apostol, T.M. (1985): Mathematical Analysis, Narosa.
2. Rudin, W. (1976): Principles of Mathematical Analysis, McGraw Hill.
3. Goldberg, R.R.: Methods of Real Analysis.


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| **5STAT702** | **Linear Algebra (Marks 60, Credit 2)** | **40** |
| | Notion of vector space, n-dimensional vector space, subspaces, union and intersection of subspaces, direct sum, projection in a vector space, Orthogonal projection, Projection operator (finite dimensional). | 12 |
| | Idempotent matrix: its properties and use as a projector. | 5 |
| | Kronecker product, trace operator and its properties. | 2 |

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| | Generalized inverse, Moore – Penrose inverse. | 5 |
| | Characteristic roots and vectors, Cayley-Hamilton theorem, algebraic multiplicity, normal matrix, spectral decomposition, singular value decomposition. | 10 |
| | Simultaneous diagonalisation of two Q. F's., Extrema of Q. F's | 6 |

***References**:*


1. Rao, C.R.: Linear Statistical Inference and its Applications, Wiley.
2. Graybill, F.A.: Matrices with Application in Statistics.
3. Searle, S.R.: Matrix Algebra Useful for Statistics.
4. Hadley, G.: Linear Algebra.
5. Rao, A.R. & Bhimasankaram, P.: Linear Algebra.


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| **5STAT703** | **Sampling Distribution (Marks 60, Credit 2)** | **40** |
| | Non-central chi-square, t and F distributions. | 6 |
| | Distribution of X'AX. | 2 |
| | Fisher-Cochran's Theorem and related results. | 5 |
| | Random sampling from $N_p(\mu,\Sigma)$, MLE's of $\mu$ and $\Sigma$ and their stochastic independence. | 4 |
| | Central Wishart distribution using Bartlett's decomposition and its properties with proofs. | 10 |
| | Distribution of Hotelling's $T^2$ and Mahalanobis's $D^2$ with applications. | 4 |
| | Distribution of sample multiple correlation coefficient. | 3 |
| | Distribution of partial correlation coefficient. | 3 |
| | Distribution of regression coefficient vector. | 3 |

***References:***


1. Rao, C.R.: Linear Statistical Inference and its Applications, Wiley.
2. Anderson, T.W.: Introduction to Multivariate Analysis.
3. Kshirsagar, A.M.: Multivariate Analysis.

4. Srivastava, M.S. and Khatri, C.G.: Introduction to Multivariate Statistics.

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| **5STAT704** | **Sample Survey (Marks 60, Credit 3)** | **30** |
| | Concepts of sampling design, sampling scheme and sampling strategy, Horvitz – Thompson method of estimation, mean per distinct unit estimator of population mean with reference to SRSWR with varying probability with and without replacement, Des Raj method of estimation, Murthy's underlying principle and its application in PPS without replacement sampling, symmetrized Des Raj estimator, sampling strategy due to Rao, Hartley and Cochran scheme of sampling. | 16 |
| | Sampling on two successive occasions with probability sampling on both. | 4 |
| | Nonresponse: Hansen-Horvitz callback method, Politz-Simmons' not-at-home method. | 4 |
| | Randomized response techniques – both qualitative and quantitative | 6 |

***References:***

1. Cochran: Sampling Techniques, Wiley
2. Des Raj.
3. Murthy.
4. Chaudhury & Mukerjee: Randomized Response.
5. Chaudhury & Stenger: Theoty of Statistical Survey Sampling.
6. Sinha & Hedayat.
7. P. Mukherjee.

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| **5STAT705** | **Linear Models (Marks 60, Credit 2)** | **35** |
| | Linear models, estimability and BLUE, estimation space and error space, method of least squares, Gauss-Markov theorem, SS due to Linear functions of observations, canonical forms, F-statistic in connection with the general linear hypothesis. | 14 |
| | Application of g-inverse and projection operators in connection with | 5 |

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| | BLUE's and related results. | |
| | Generalized LS estimation under linear restriction on parameters. | 3 |
| | Scheffe's and Tukey's multiple comparison techniques. | 3 |
| | Tukey's test for non-additivity, Analysis of covariance in the general setup, nested classification. | 10 |

***References:***


1. Rao, C.R. Linear Statistical Inference and its Applications.
2. Graybill, F.A.: Linear Models vol. I.
3. Graybill, F.A.: Matrices with applications in Statistics.
4. Kshirsagar, A.M : Linear Models.
5. Searle: Linear Statistical Methods.
6. Joshi, D.D.
7. Chakraborty, M.C.


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| **5STAT706** | **Operations Research (Marks 60, Credit 2)** | **45** |
| | Definition and scope of OR, Phases in OR. | 2 |
| | Review of Linear Programming Problem, methods of solution, duality in LPP, transportation and assignment problem with proofs of relevant results, traveling salesman problem. | 14 |
| | Inventory models, costs and distributions, EOQ model including the case with price break-ups. | 6 |
| | Queueing models – M/M/1 : (∞/FIFO) ; M/M/C : ((∞/FIFO) ; M/M/1 : (N/FIFO) models. | 7 |
| | Sequencing models, Sequencing n jobs on two machines. | 3 |
| | Elements of game theory two – person games, pure and mixed strategies, existence of solution and uniqueness of value in zero – sum games, finding solutions in 2x2, 2xm and mxn games. | 8 |
| | Introduction to networks, determination of floats and critical paths, CPM & PERT. | 5 |

***References:***

1. Goel and Mittal: Operations Research, Sultan Chand.

2. Kanti Swarup, P.K. Gupata & M.M. Singh (1985): Operations Research, Sultan Chand.

3. Philips, D.T., Ravindran, A. and Solberg, J: Operations Research, Principles and Practices.

4. Taha, H.A.: Operations Research: An Introduction, 6th Ed. 1997 Prentice–Hall of India.

**5STAT707 C++ Programming (Marks 40, Credit 2) 40**

Basics of C++ language: Input / Output Statements, Control 40

Structures.

Functions: Library functions, user-defined functions, functions declaration.

Pointers: manipulation of pointers data.

Applications to some statistical problems.

Monte Carlo Simulation.

Computer work.

***References****:*

1. Lafore, R. Object-Oriented Programming in Microsoft C++.

2. Balagurusamy: C++ Programming.

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| **5STAT800** | **Basics of Probability and Statistics (Marks 100, Credit 4)** | **54** |
| **(Open)** | **Descriptive Statistics**: Collection, tabulation and diagrammatic representation of data; Frequency distribution, graphical representation of a frequency distribution, histogram, frequency polygon, ogives; Common measures of central tendency and dispersion, coefficient of variation.<br>Bivariate frequency distribution, scatter diagram, simple correlation and regression. | 16 |
| | **Probability**: Random Experiments, Sample space, Events, classical definition of probability, Theorem of Total probability, Conditional probability, Statistical independence of events, product rule for probability, related problems.<br>Random variables, expectation and variance of random variables, moments and moment generating function, Chebyshev inequality.<br>Binomial, Poisson and Normal distributions, related problems. | 18 |
| | **Statistical Inference**: Population and sample; parameter and statistic, sampling distribution of a statistic, basic concepts of estimation – unbiasedness and consistency, notion of uniformly minimum variance unbiased estimator, standard error.<br>Basic concepts of tests of significance, tests for means of normal distribution, Student's t, Fisher's t and paired t tests, testing equality of means of several normal populations, least significant difference; $\chi^2$ tests for independence in contingency tables.<br>ANOVA for one-way and two-way classified data. | 20 |

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| **5STAT801** | **Probability and Measure Theory (Marks 60, Credit 2)** | **56** |
| | Classes of sets, Fields, Sigma fields, Minimum Sigma field, Borel Sigma field in R, Sequence of sets, limsup and liminf of a sequence of sets. Measure, Probability Measure, Properties of a measure. | 15 |
| | Measurable functions, Random variables, D.F., decomposition of D.F., Statement of correspondence theorem, Generating function and Characteristic function, Inversion theorem, Continuity theorem | 15 |

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| | (statement only) | |
| | Integration of a measurable function with respect to a measure, Monotone convergence theorem, Fatou's lemma, Dominated Convergence Theorem. | 8 |
| | Sequence of random variables, Almost sure convergence. | 4 |
| | Borel-Cantelli lemma, Independence, Hajek-Reyni inequality, Kolmogorov inequality, strong law of large numbers. | 8 |
| | Central Limit Theorem for iid random variables, CLT for a sequence of independent Random variables. Statements of Lindeberg-Feller & Liapounoff's theorem. | 4 |
| | Product measure and Fubini's theorem (Statements only) | 2 |

***References:***


1. A.K. Basu: Measure Theory & Probability.
2. B.R. Bhat: Modern Probability Theory.
3. P. Billingley: Probability & Measure.
4. J.F.C. Kingman & S.J. Taylor: Introduction to Measure and Probability.
5. R.G. Laha & V.K. Rohatgi : Probability Theory.
6. R. Ash: Real Analysis and Probability.
7. C.W. Burrill: Measure Theory & Probability
8. H. Cramer: Mathematical Statistics.
9. C.R.Rao: Linear Statistical Inference and its Applications.
10. Bartle: The Elements of Integration.
11. K.R. Parthasarathi: Introduction to Probability and Measure.


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| **5STAT802** | **Stochastic Process (Marks 60, Credit 2)** | **30** |
| | Introduction to Stochastic processes, classification of Stochastic processes according to state space and time domain, Markov chain with finite and countable state space, n-step transition probability and its limit, Chapman – Kolmogorov equation, Stationary distribution classification of states, Random Walk and gambler's ruin | 12 |

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| | problem. | |
| | Discrete state space continuous time Markov chain: Poisson process, birth and death process. | 8 |
| | Renewal Theory: Elementary renewal theory, statement and uses of key renewal theorem. | 4 |
| | Branching process: Galton – Watson branching process, probability of ultimate extinction. | 4 |
| | Continuous process: Brownian motion. | 2 |

***References:***


1. J. Medhi: Stochastic Processes.
2. S.M. Ross: Introduction to Probability Models.
3. Karlin and Taylor: A First course in Stochastic Processes.
4. B.R. Bhat: Stochastic Models.


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| **5STAT803** | **Large Sample Theory (Marks 40, Credit 2)** | **20** |
| | Convergence in distribution of random variables, Scheffe's theorem, Slutsky's theorem. Characteristic function of random vector and the Multivariate CLT (without proof)), δ-method of deriving the asymptotic distribution of a smooth function of an asymptotically normal sequence. | 10 |
| | Sample statistics: empirical distribution function, strong consistency, asymptotic distribution of the cdf. | 4 |
| | Quantiles: asymptotic normality. | 3 |
| | Order Statistics: Relation to quantiles, asymptotic distribution of extreme order statistics. | 3 |

***References:***


1. P. Billingsley.
2. C.R. Rao: Linear Statistical Inference and its Applications, Wiley.

3. R.J. Serfling: Wiley.
4. S.S. Wilks: Wiley.
5. H. A. David.
6. E. L. Lehmann: Asymptotic Theory, Springer.

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| **5STAT804** | **Design of Experiments (Marks 80, Credit 3)** | **54** |
| | Block Designs – concepts of connectedness, orthogonality and balance: intrablock analysis. | 8 |
| | Variance Balance Design, BIB, Lattice and PBIB designs. | 10 |
| | Justification of missing plot techniques. | 2 |
| | Latin square and Youden square designs. | 5 |
| | Recovery of intrablock information, applications in BIBD. | 5 |
| | Construction of mutually orthogonal Latin Squares (prime power case), BIBD with resolvability. | 7 |
| | Factorial experiments, confounding and balance in symmetric factorials (prime power case), examples of ($s^m$, $s^{m-1}$) and ($s^3$, $s^2$), ($s^4$, $s^3$) designs without proof. | 12 |
| | Response surface experiments, first order designs and orthogonal designs | 5 |

***References:***


1. Chakraborty, M.C.: Mathematics of Design and Analysis of Experiments.
2. Kempthorne, O.
3. Cochran, W.G. & Cox, G.M.
4. Federer.
5. Das & Giri.
6. Dey, Aloke (1986): Theory of Block designs (Wiley Eastern).
7. Joha, P.W.M. (1971).
8. Nigam, A.K. Puri, P.D. & Gupta, V.K.
9. Montgomey, D.C. (1976).
10. Myers, R.H. (1971) : Response Surface Mthodology (Allyn and Bacon).
11. Box & Draper.
12. Khuri & Cornell.

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|---|---|---|
| **5STAT805** | **Econometrics and Time Series Analysis (Marks 80, Credit 3)** | **45** |
| | Nature of Econometrics. Classical General Linear Regression Model (CLRM): Specification, Estimation, Testing, and Interval Estimation. Small and Large Sample Properties of OLS estimators. The problem of multi-collinearity (MC): Effect of exact and near-exact MC estimation and testing of regression parameters. Dummy variable regression and its use in determination of seasonality. Regression Diagnostics. | 18 |
| | CLRM with non-spherical disturbance. GLS technique. Aitkin's theorem. Heteroscaedastic disturbance: Consequence on OLS estimation. Tests for heteroscaedasticity. Estimation and testing in CLRM with heteroscaedastic disturbance. | 6 |
| | Autocorrelated disturbance: Consequence on OLS estimation Tests for autocorrelation. Estimation and testing in CLRM with autocorrelated disturbance. | 5 |
| | Simultaneous equation models: identification and estimation. | 4 |
| | Review of classical decomposition method. Smoothing of time series using filters. Representation of time series as a stochastic process. Weakly and strongly stationary processes and their examples. Ergodicity. Autocorrelation and partial autocorrelation functions and their properties. AR, MA, ARMA models and their properties. Identification, estimation and diagnostic checking of ARMA models. Forecasting. | 12 |

***References:***


1. W.H. Greene (2002): Econometric Analysis.
2. Mittlehammer, C.R., G.G. Judge, D Miller (2001): Econometric Foundations, Cambridge.

3. Johnston & Dinardo (1990): Econometric Methods, McGraw Hill.
4. Judge, L. et al.: Theory and Practice of Econometrics.
5. Malinvaud, E. (1966): Theory of Econometrics.
6. Their, H. (1982): Introduction to the Theory and Practice of Econometrics

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| **5STAT901** | **Estimation Theory (Marks 70, Credit 3)** | **57** |
| | Sufficiency minimal Sufficiency, Factorization theorem in the dominated case (without proof), completeness, ancillarity, Basu's theorem. Unbiased estimation, Lehmann-Scheffe theorem, Chapman-Robbins inequality, Rao-Cramer Lower bound in the multiparameter case (statement only), Bhattacharyya inequality. | 18 |
| | Equivariant estimation with emphasis on location and scale, minimum risk equivariant estimators, Pitman estimator. | 10 |
| | Large sample considerations: consistency of estimators, consistency of the minimum likelihood estimator under Cramer type conditions, asymptotic normality of the one-step MLE, method of scoring (including the multiparameter set–up in all cases), asymptotic efficiency, Hodges' example, Bahadur's theorem on supper – efficient estimators (without proof). | 16 |
| | Confidence sets: relation with hypothesis testing; optimum confidence intervals. | 6 |
| | Resampling procedures in the context of estimation: the jackknife and bootstrap. | 7 |

***References:***

1. Goon A.M., Gupta M.K., and Dasgupta, B.: An Outline of Statistical Theory, Vol 2, World Press.
2. Lehmann, E.L. and Casella, G.:Theory of Point Estimation, 2nd Ed, John Wiley.
3. Rao, C. R. (1973): Linear Statistical Inference & its Applications, Wiley.
4. Shao, J and Tu, D. (1995): The Jack Knife and Bootstrap, Springer.
5. Zacks, S. (1971): Theory of Statistical Inference, John Wiley.

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| **5STAT902** | **Testing of Hypothesis (Marks 70, Credit 3)** | **54** |
| | Neyman-Pearson lemma, monotone likelihood ratio property, one-sided hypothesis against a one sided alternative, generalized Neyman-Pearson lemma (without proof), two sided hypothesis in a one parameter exponential family, least favourable distributions. | 28 |
| | Locally best test (One sided), similar test, Neyman structure, UMPU test for a one-parameter exponential family. | 8 |
| | Likelihood Ratio test (LRT), Asymptotic distribution of LRT statistics under simple null hypothesis (real parameter only), Wald's test and Rao's score test, consistency of the LR test for simple hypothesis, Bartlett's test for homogeneity of variances. | 8 |
| | Sequential tests, SPRT and its properties, fundamental identity, OC and ASN, Wald's equation for ASN. | 10 |

***References:***


1. Lehmann, E.L.: Testing Statistical Hypotheses.
2. Ferguson, T.S.: Mathematical Statistics-A Decision Theoretic Approach.
3. Rohatgi, V.: An Introduction to Probability and Mathematical Statistics.
4. Rao, C.R.: Linear Statistical Inference and its Applications.
5. Kendall, M.G. and Stuart, A.: The Advanced Theory of Statistics, Vol. II.
6. Goon, A.M., Gupta M.K. and Dasgupta, B.: An Outline of Statistical Theory, Vol II.


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| **5STAT903** | **Nonparametric Methods (Marks 70, Credit 3)** | **35** |
| | Runs test for randomness, Kolmogorov – Smirnov goodness of fit test, One sample location and scale problems, Wilcoxon signed rank statistic, median test, two sample homogeneity problem, Wolfowitz runs test and the two sample Kolmogorov-Smirnov test. | 10 |
| | One and two-sample U-statistics, statement of the asymptotic normality of U-statistics, linear rank statistics, statement of the asymptotic normality under the hypothesis. | 8 |

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| | Location and scale alternatives in the two sample problem, The median and the Mann-Whiteny tests, Mood's test and the normal and inverse normal scores tests. | 6 |
| | One –way and two – way classification, Kruskal – Wallis and Friedman's tests | 3 |
| | Measures of rank correlation: The Spearman's rho and Kendall's tau. | 4 |
| | Confidence intervals related to the Median and the Mann-Whitney tests in one and two sample problems. | 4 |

***References:***

1. Gibbons.
2. Outline Vol2.
3. Randles & Wolfe.

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| **5STAT904** | **Decision Theory (Marks 70, Credit 3)** | **35** |
| | Elements of decision problem and associated concepts, statistical games and point estimation and testing of hypothesis as particular cases. | 10 |
| | Rao-Blackwell theorem (statement only). | 1 |
| | Statistical games with finite set of states of nature : The risk set, lower boundary set and the lower quantant, relation to admissible, minimax and Bayes rules. | 10 |
| | Statement of the separating hyperplane theorem, existence and admissibility of Bayes rules, completeness of the class of Bayes rules. | 6 |
| | Computation of minimax tests for one-sided hypothesis in MLR families. | 8 |

***References:***

1. Ferguson, T. S.: Mathematical Statistics – A Decision Theoretic Approach, Academic Press.

2. Berger, J. O.: Statistical Decision Theory, Springer.

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| **5STAT905** | **SQC and Reliability (Marks 70, Credit 2)** | **37** |
| | **SQC:** General Theory and review of control charts for attributes and variable data: OC and ARL of control charts; moving average and exponentially weighted moving average charts; CUSUM charts using V-masks and decision intervals. | 8 |
| | Continuous sampling plans of Dodge type and Wald-Wolfowitz type and their properties. | 4 |
| | Capability indices CP, CPK and CPM. | 3 |
| | Acceptance sampling plan for attributes: Sequential sampling plan, Mil. Std. plan. | 2 |
| | **Reliability:** Reliability concepts and measures; components and systems, coherent systems; reliability of coherent systems; cuts and paths; modular decomposition; bounds on systems reliability and reliability importance of components. | 8 |
| | Life distributions, reliability function; hazard rate; common life distributions - exponential, Weibull and gamma. | 4 |
| | Notions of ageing; IFR, IFRA, NBU, DMRL and NBUE and their duals; loss of memory property of the exponential distribution. | 4 |
| | Reliability estimation based on failure time in variability censored life-tests. | 4 |

***References:***


1. D.C. Montgomery (1985): Introduction to Statistical Quality Control. Wiley.
2. Wetherill, G.B. (1977): Sampling Inspection and Quality control, Halsteed Press.
3. Wetherill, G.B. Brown, D.W.: Statistical Process Control Theory and Practice, Chapman & Hall.
4. Barlow, R.E. and Proschan, F (1985): Statistical Theory of Probability and Life Testing, Holt, Rinehart & Winston.

5. Lawless, J.F. (1982): Statistical Models and Methods of Life Data, John Wiley.

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| **5STAT906** | **R Programming (Marks 50, Credit 2)** | **49** |
| | Basics of R programming; numerical arithmetic, simple manipulation of vectors, descriptive statistics on univariate data.<br>Bivariate data, factors, descriptive statistics.<br>Arrays and matrices, matrix operations.<br>Lists and data frames, *attach, detach, read.table, scan*; accessing data sets from other R packages. | 15 |
| | Probability distributions, Q-Q plots, K-S tests, one and two sample tests.<br>Grouped expressions, conditional statements, loops, for and while.<br>Functions in R; named arguments and defaults, assignments within functions, dropping names in a printed array, scope and class of objects, generic functions and object orientation.<br>Statistical models in R; Formulae for statistical models, linear model generic functions for extracting model information, ANOVA, updating fitted models, GLM, NLS, maximum likelihood models. | 18 |
| | Graphical procedures, high level and low level plotting commands, graphical parameters.<br>Standard packages from R; some nonstandard statistical models, Dynamic graphs. | 16 |

***References:***


1. An Introduction to R; manual from www.r-project.org

## SPECIAL PAPERS

**2 (Two) papers to be offered from:**

1. Advanced Data Analytic Techniques (ADDAT)
2. Advanced Multivariate Analysis (ADMA)
3. Applied Multivariate Analysis (APMA)
4. Advanced Design of Experiments (ADDE)
5. Advanced Sample Survey (ADSS)
6. Advanced Time Series Analysis (ADTSA)
7. Advanced Econometric Methods (ADEM)
8. Advanced Econometric Applications (ADEA)
9. Advanced Econometrics (ADE)
10. Statistical Genomics and Bioassay (SGB)
11. Survival Analysis (SA)
12. Advanced Inference (ADI)
13. Advanced Operations Research (ADOR)
14. Reliability and Survival Analysis (RSA)

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| **Advanced Data Analytic Techniques (ADAT): Marks 100, Credit 4** | **54** |
| Overdispersed Data | 14 |
| Missing Data | 12 |
| Data with measurement error. | 16 |
| Case Studies. | 12 |

***References**:*


1. P.J. Diggle, K.Y.Liang & S.L. Zeger: Analysis of Longitudinal Data.
2. D. Hard & M. Crowder: Preacucal Longitudinal Data Analysis.
3. R. Carrol, D. Ruppert & L.A. Stefansky: Measurement Error in Nonlinear Models.

4. P.McCullagh & A.J. Nelder: Generalized Linear Models.

**54**

**Advanced Multivariate Analysis (ADMA): Marks 100, Credit 4**

| | |
|---|---|
| Improved estimation of mean vector: James Stein estimator and its modifications. | 6 |
| Heuristic approach to test construction: union – intersection and step – down procedures and their applications to various problems involving normal distribution. | 7 |
| Invariant tests; Optimum properties of Hotelling's $T^2$ – test. | 5 |
| Test of covariance matrices: Sphericity test, test of independence, test of equality of several covariance matrices. | 8 |
| Testing equality of several normal populations. | 4 |
| Multivariate Behrens – Fisher problem. | 3 |
| Some admissibility results: Admissibility of Hotelling's $T^2$ – test and the LRT for testing independence. | 4 |
| General linear hypotheses and MANOVA. | 10 |
| Confidence regions and simultaneous confidence intervals involving mean vectors, dispersion matrices and regression matrices. | 7 |

***References:***

1. Anderson, T.W. (1984): An introduction to Multivariate Statistical Analysis, 2nd Ed, John Wiley.
2. Giri, N.C. (1977): Aspects of Multivariate Statistical Theory, John Wiley.
3. Sirvastava, M.S. and Khatri, C.G. (1979): An Introduction to Multivariate Statistics, North Holland.
4. Muirhead, R. J.: Aspects of Multivariate Analysis, Wiley.

**Applied Multivariate Analysis (APMA): Marks 100, Credit 4** **41**

| | |
|---|---|
| Organization and representation of multivariate data. | 6 |
| Dimension Reduction Techniques : | |
| a) Principal Component Analysis Concept, Computation, Large sample Inferences. | 5 |
| b) Canonical Correlation Analysis: Concept, Computation, Large sample, Inferences. | 5 |
| c) Exploratory Factor Analysis: Concept, Factor model, estimation of factor landings, factor rotation, estimating factor scores, Model fit. | 5 |
| Multivariate Analysis of Variance: One-way and two-way classified data with one observation per cell. | 5 |
| Discriminate Analysis: Likelihood ratio, Bayes and minimax procedures, Discrimination between two multivariate normal populations with common dispersion, Sample discriminate function, estimation, Fisher's method for discriminating among several populations. | 6 |
| Cluster Analysis: Proximity measures, Hierarchical clustering techniques: single, complete and average linkage algorithms. Non-hierarchical clustering techniques: K-means method. | 5 |
| Multidimensional Scaling: Classical Metric Scaling, Non-metric scaling . | 4 |

***References:***


1. Johnson, R.A. and Wichern, D.W.: Applied Multivariate Statistical Analysis.
2. Kshirsagan, A.M. Multivariate Analysis.
3. Morrison, D.F. Multivariate. Statistical Methods.
4. Seber, G.A.F. Multivariate Observations.
5. Mardia, Kent and Bibby.


**Advanced Design of Experiments (ADDE): Marks 100, Credit 4 60**

| | |
|---|---|
| PBIB design: Classification of two associate association schemes, uniqueness GD association schemes Construction of GD designs. | 15 |
| Fractional factorial designs: ($1/2^k$ of $2^n$ experiments only) without blocking. | 8 |
| Response surface designs: Variance function, rotatable designs, analysis, some methods of construction of second order rotatable designs. | 16 |
| Optimum designs: different optimality criteria, optimality of standard designs, namely RBD, LSD, BIBD, YSD; optimality of BBD and GYD (regular setting). | 12 |
| | 9 |

***References:***


1. Kempthorne, O.
2. Cochran & Cox.
3. Box & Hunter.
4. Raghava Rao (1971).
5. Shah & Sinha: Theory of Optimal Designs (Springer –Verlag).
6. Hedayat & Wallis (1978): Ann. Statist.


| **Advanced Sample Survey (ADSS): Marks 100, Credit 4** | **53** |
|---|---|
| Unified theory of survey sampling, non existence theorems of Godambe (JRSSB, 1955) and Basu (in Godambe and Sprott's Foundations of Inference in survey Sampling, 1971**)** concerning uniformly minimum variance unbiased estimators; admissibility, sufficiency and minimal sufficiency, complete class theorem, unordering as a means to construct a complete class. | 15 |
| Issued in a small area estimation – Synthetic and generalized regression estimators, Kalman Filtering Technique. | 10 |
| Non-Sampling errors and biased responses, randomized responses for variables, errors in surveys, modeling observational errors, estimation of variance components, application of longitudinal studies (repetitive | 10 |

surveys).

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| Variance estimation, method of random groups, balanced half samples (IPNSS), Jack-knife method. | 8 |
| Introduction to Superpopulation models, optimal design – unbiased strategies and optimal model-unbiased prediction under simple regression models. | 10 |

***References:***


1. C.M. Cassel, C.E. Sarndal. & J.H. Wretman: Foundation of Inference in Survey Sampling.
2. A. Chaudhuri & J.W.E. Vos: Unified Theory and Strategies of Survey Sampling.
3. A.S. Hedayat & B.K. Sinha: Design and Inference in Finite Population Sampling.
4. P. Mukhopadhyay: Inferential Problem in Survey Sampling.
5. P. Mukhopadhyay: Small Area Estimation in Survey Sampling, Narosa.
6. C.E. Sarndal, B. Swensson & J. Wretman: Model Assisted Survey Sampling.


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| **Advanced Time Series Analysis (ADTSA): Marks 100, Credit 4** | **55** |
| Review of stationary processes – stationarity, autocovariance function, and its properties. Ergodicity. Sufficient conditions for ergodicity, ergodicity property of WN, AR, MA, ARMA processes. Autocovariance generating functions, ACGF for WN, AR, MA, ARMA processes. Review of identification, estimation and diagnostic checking of ARIMA processes. Specification and estimation of VARMA model. State – Space time series Models: State-Space representation of a dynamic system. Illustration using AR (p), MA(q), ARMA (p, q) | 20 |
| Forecasting: Minimum MSE forecast using ARIMA and VARMA models. Weiner-Kolmogorov (WK) prediction formula. Illustrations using ARMA model State –space Modeling. Kalman filter. Use of Kalman filter to calculate least squares forecast for the state vector and the vector of variables. Exact finite sample s-period ahead forecast with Kalman filter. | 10 |
| Non-stationary processes. Unit root tests and their large sample | 10 |

properties. Cointegration. Error correction model. Variance non-stationarity. Specification, properties, estimation and testing using ARCH and GARCH models.

The spectral representation of a stationary time series. Spectral density function and its properties. Spectral density of AR, MA, ARMA processes. Correspondence between time domain and frequency domain – Bochner's theorem, Weiner – Khinchine theorem. Estimation of spectral density function. Schuster's periodogram intensity function and its inconsistency. Nonparametric estimation of spectral density function. 15

***References**:*


1. Anderson, T.W. The Statistical Analysis of Time Series.
2. Greene, W.H. : Econometric Analysis
3. Hannan: Time series Analysis
4. Brockwell and Davis (2002): Introduction to Time Series and Forecasting, Springer.


**Advanced Econometric Methods (ADEM): Marks 100, Credit 4** **54**

Estimation and Testing methods in Econometrics: Estimation: Maximum Likelihood, Quasi-Maximum Likelihood, Simulated Maximum Likelihood, GMM and EM estimation. Statement of the large sample properties of the estimators. 10

Tests based on ML principle: LR test, Rao's Score test, Wald's test. White's information matrix test, test for non-nested hypothesis. 5

Models with lagged variables: The lag and difference operators. Finite and infinite lag models. Autoregressive distributed lag models. Forecasting. 8

Discrete and limited dependent variable models : Specification, estimation of (i)Binary choice models and its extension (ii) Multivariate probit model (iii) multivariate logit model (iv) count 15

| | |
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| model (v) truncated and censored regression model (vi) Duration model. | |
| Panel Data Models: Specification, Estimation and Testing in the context of fixed, mixed and random effects models. GMM estimation of dynamic panel data models. | 4 |
| Specification testing and diagnostic checking. Inferential problems in mis-specified models. | 4 |
| Introduction to Nonparametric and semi-parametric regression. | 8 |

***References:***


1. Greene, W. H. (2002): Econometric Analysis.
2. Mittlehammer, C. R., Judge, G. G. and Miller, D. (2001): Econometric Foundations, Cambridge.
3. Johnston and Dinardo (1990): Econometric Methods, McGraw Hill.
4. Judge et al. Theory and Practice of Econometrics.
5. Malinvaud, E.: Theory of Econometrics.
6. Theil, H. (1982): Introduction to the Theory and Practice of Econometrics.


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|---|---|
| **Advanced Econometric Applications (ADEA): Marks 100, Credit 4** | **50** |
| Income and allied size distributions: Stochastic models of income distribution, Measurement of income inequality, problems of measurement, Indian studies on inequality and poverty. | 10 |
| Advanced demand analysis: Demand systems, zero expenditure and corner solutions, nonlinear budget frontiers, rationing, sources of dynamics in consumer behaviour, durable goods, non-parametric demand analysis. | 10 |
| Production analysis: Frontier production function, measurement of productivity and technical change, flexible forms, aggregation, properties and estimation of multi-output production and cost functions. | 10 |

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| Estimation of structural models of firm behaviour: Dynamic programming models, policy effects on productivity, capital formation and product – mix of firms, models of firm heterogeneity – measurement of product quality and efficiency differences among firms. | 10 |
| Empirical models of the labour market: Duration analysis, labour supply and labour demand functions including the impact of unionization, studies on the Indian labour market. | 10 |

***References:***


1. Sen, A.: On Economic Inequality, Oxford.
2. Sen, A.: Poverty and Famine: An Essay on Entitlement and Deprivation, Oxford.
3. Deaton and Muellbauer. : Economic theory and Consumer Behaviour, Cambridge University Press.
4. Kumbhakar and Lovell: Stochastic Frontier Analysis, Oxford.


| **Advanced Econometrics (ADE): Marks 100, Credit 4** | **55** |
|---|---|
| Capital Asset Price Model (CAPM). Estimation of CAPM by L.S., SURE and IV techniques; properties of the estimators. Statistical testing of the CAPM hypothesis. | 5 |
| Portfolio Analysis: Individual Portfolio and Market portfolio. Efficient portfolio rule. N-asset Mean-Variance (MV) portfolio model of Markkovich. Tangency portfolio. M-V frontier. Sharpe ratio. M-V portfolio choice with (i) predictable returns (ii) overlapping returns. Use of CAPM in portfolio analysis. | 10 |
| Modeling of asset returns: Test of White Noise (WN) hypothesis based on sample autocorrelations and variance rations. Specification, estimation and diagnostic checking of ARIMA model. Forecasting of asset returns. Multivariate linear time series model : Specification and Estimation of VARMA. Analysis of Non-stationary financial data: unit root hypothesis, DF test. Co-integration. Error-correction model. Prediction of asset- return using variance – ratio, dividend – price | 16 |

ratio and lead – lag. Factor model of asset returns.

Modeling of asset price: Martingales and Random walk. Testing of Efficient market hypothesis. Statistical inference based on stochastic models of price dynamics. Modeling of option price in complete market. Black –Scholes formula (statement only) and its application. 12

Modeling and analysis of asset risk: Stochastic volatility model (SVM) Estimation of volatility in random walk. Risk modeling and estimation using of ARCH, GARCH and ARAM-GARCH models. Analysis of extreme risk. Estimation of Value-at-Risk (VaR). Confidence interval estimation of VaR using resampling technique. 12

***References:***


1) Camble, J.Y, A.W. Lo and A.C. MacKinlay (1997): The Econometrics of Financial Markets. Princeton University Press.

2) Gourieroux, C and J.Jasiak (2004): Financial Econometrics: Problems, Models and Methods.

3) Bodie, Z, A. Kane and A.J. Marcus (2002): Investments, McGraw-Hill, 5th edition.

4) Brockwell and Davis (2002): Introduction to Time Series and Forecasting, Springer.


**Statistical Genomics and Bioassay (SGB): Marks 100, Credit 4** **52**

**Statistical Genomics:** 25

Introduction, Mendellian Genetics and Cytogenetics, Population Genetics, Quantitative Genetics, Molecular Genetics.Genetic Mapping, DNA sequencing, Single locus and two loci models. QTL mapping.

**Bioassay:** 27

Types of Biological Assays. Direct Assays, Ratio Estimators, asymptotic distributions. Fieller's Theorem .

Regression approaches to estimating dose – response relationships. Logit and probit approaches when dose – response curve for standard

preparation is unkuown, Quantal responses, Method of estimation of parameters, estimation of extereme quantiles, does allocation schemes, polychotomous quantal response.
Estmation of points on the quantal response function.

***References:***


1. C.C.Li: First Course on Population Genetics.
2. W.J. Ewens: Mathematical Population Genetics.
3. P. Nagylaki: Introduction to Theoretical Population.
4. A. Krogh & G. Mitchison: Biological Sequence Analysis – Probabilistic Models of Proteins & Nucleic Acids.
5. Z. Govindarajulu: Statistical Techniques in Bioassay.
6. D.J. Finney: Statistical Methods in Bioassay.
7. D.J. Finney: Probit Analysis ($3^{rd}$ edition).


| **Survival Analysis (SA): Marks 100, Credit 4** | **55** |
|---|---|
| Introduction, Basic Quantities and Models. | 8 |
| Censoring and Truncation. | 7 |
| Topics in univariate estimation. | 8 |
| Nonparametric estimation. | 7 |
| Nonparametric estimation. | 7 |
| Semi-parametric properties | 6 |
| Regression Diagnostics. | 6 |
| Multivariate Survival Analysis. | 6 |

***References:***


1. D.R. Cox & D. Oakes: Analysis of Survival Data.
2. A. J. Grouss & A.V. Clark: Survival Distribution – Reliability Applications in the Biomedical Sciences.
3. R.E.E. Johnson & N.L. Johnson: Survival Models and Data Analysis.
4. R.G. Miller: Survival Analysis.

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|---|---|
| **Advanced Inference (ADI): Marks 100, Credit 4** | **58** |
| Week compactness of critical functions (statement only) and its applications, generalized Neyman-Pearson Lemma, closure of the risk set from below in a two-action problem. | 8 |
| Maximin tests, most stringent tests, Hunt-Stein theorem. | 10 |
| EM algorithm. | 6 |
| Robustness concepts, Gateaux derivatives of von Mises functionals, influence curves – examples; robustness of M-estimators. | 12 |
| Multiple decision problems, problems on classification and ranking. | 10 |
| Invariant priors and invariant Bayes rules (statement only), non-informative and conjugate priors, posterior analysis. | 12 |

***References:***


1. Lehmann, E. L.: Testing Statistical Hypotheses, 2nd ed.
2. Lehmann, E. L.: Theory of Point Estimation.
3. Lehmann, E. L. and Casella, G.: Theory of Point Estimation, 2nd ed.
4. Berger, J. O.: Statistical Decision Theory, Springer.
5. Serfling, E.: Approximation Theorems in Mathematical Statistics, Wiley.
6. Casella, G., and Berger, J. O.
7. McLachlan and Krishnan: The EM Algorithm.


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| **Advanced Operations Research (ADOR): Marks 100, Credit 4** | **56** |
| Sensitivity analysis in linear programming problems. | 4 |
| Nonlinear programming: graphical method, classical optimization technique, Kuhn-Tucker theorem, Wolfe's algorithm in quadratic programming. | 10 |
| Dynamic programming, Bellman's principle of optimality, general formulation, applications. | 6 |
| Inventory problems, deterministic model, multiple item static model with storage limitation, continuous review model, ABC analysis. | 8 |

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| Stochastic programming, chance-constrained programming under normality. | 5 |
| Integer programming, branch and bound and cutting plane method. | 6 |
| Simulation: Monte-Carlo method, generation of random observations from a few standard distributions. | 6 |
| Replacement problems, replacement of items that depreciate, block and age replacement policies, staffing problem. | 6 |
| Goal programming. | 5 |

***References:***


1. Hadley.
2. Gass.
3. Taha.
4. Kambo.
5. Goel and Mittal.
6. Sharma.


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| **Reliability and Survival Analysis (RSA): Marks 100, Credit 4** | **60** |
| Life distributions, survival functions, hazard rate, hazard function, residual life time, mean residual life function, one-one correspondence of these functions, common life distributions, exponential, Weibull, gamma, Makeham, Pareto, Rayleigh and lognormal distribution. | 5 |
| Notions of ageing, IFR, IFRA, DMRL, NBU, NBUE, HNBUE classes and their duals for continuous and discrete setups. Exponential distribution and its non-ageing property, ageing properties of other common life distributions, closure under formations of coherent structures, convolutions and mixtures. | 12 |
| Univariate shock models and life distributions arising from shock models, vector concept of hazard rate, multivariate lack of memory property, properties of multivariate exponential distribution due to Marshall and Olkin. | 9 |

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| Maintenance and replacement policies, relevant renewal theory, availability of repairable systems, optimization of system reliability with redundancy, spare parts allocation. | 10 |
| Parametric inference for various life distributions, moments and maximum likelihood estimation, likelihood ratio tests, tests based on the MLE, type I, II and random censoring schemes, estimation and testing based on these schemes for various parametric models. | 12 |
| Stress-strength model – determination and estimation; accelerated life testing. | 12 |

***References:***


1. Barlow and Proschan.
2. Lawless, J. F. (1982): Statistical Models and Methods of Lifetime Data, Wiley.
3. Kapur and Lamberson.