PRESIDENCY
UNIVERSITY
KOLKATA

Presidency University, Kolkata
CBCS Syllabus
in
B.Sc. (Honours) Statistics
Semesters 1 – 6
(With Effect from Academic Session 2022 – 2023)

Department of Statistics
(Faculty of Natural and Mathematical Sciences)
Presidency University
Previously Hindu College (1817 – 1855),
Presidency College (1855 – 2010)
86/1, College Street, Kolkata – 700 073
West Bengal, India

CONTENT

1.1 Academic Sessions :
Odd Semester : Semester One/Three/Five
Even Semester : Semester Two/Four/Six

1.2 Skill Enhancement Elective (SEC) Courses/Papers
[Credit : 4 each, 2 paper to be selected from the list]

Semester-3	Semester-4
1. Data Analysis Using Excel and R 2. Data Analysis Using Software Packages	3. Advanced Statistical Computing using R 4. Research Methodology

In each of the Third and the Fourth Semesters, a student can choose one SEC from the corresponding list.

1.3 Discipline Specific Elective (DSE) Courses/Papers
[Credit : 6 each, 4 papers to be selected from the list]

Group-1	Group-2
1. Stochastic Processes and Queuing Theory (Theory + Practical) 2. Econometrics (Theory + Practical) 3. Advanced Statistical Methods (Theory + Practical)	1. Biostatistics (Theory + Practical) 2. Advanced Mathematical Analysis (Theory + Tutorial) 3. Operations Research (Theory + Practical) 4. Project Work (Sixth Semester)

In each of the Fifth and the Sixth Semesters, a student can choose one DSE Paper from Group-1 and one from Group-2. In the Sixth Semester, a student cannot opt for a Paper already chosen in the Fifth Semester. Before the commencement of a semester, the Department will announce the particular SEC and DSE paper(s) that may be offered depending upon the availability of faculty and resources.

1.4 Generic Elective (GE) Courses/Papers
[Credit: 6 each, 4 papers of any discipline to be selected by other Departments/Disciplines]

1. Introductory Statistics and Probability

2. Sampling and Inference

3. Applied Statistical Inference

4. Applied Multivariate and Regression Models

Scheme for Courses in B.Sc. (Honours) Statistics (CBCS)

2.1 Credit Distribution across Courses

Course Type	Credits		
	Total Papers	Theory+Practical	Theory+Tutorial
Core Courses	14	14×4+14×2 = 84	14×5+14×1=84
Skill Enhancement Elective	2	2×4=08	2×4=8
Discipline Specific Electives	4	4×4+4×2=24	4×5+4×1=24
Ability Enhancement Compulsory Language Course	1	1×4=04	1×4=4
Ability Enhancement Compulsory Environmental Science Course	1	1×4=04	1×4=4
Generic Elective	4	4×4+4×2=24	4×5+4×1=24
Total	26	148	148

2.2 Scheme for B.Sc. (Honours) CBCS Curriculum

Semester	Course Name	Paper Code	Course Name	Credits	Marks
I	Ability Enhancement Compulsory Course–I	STAT01AEC01	English Communication / Environmental Science	4	100
	Core course–I	STAT01C01	Descriptive Statistics	4	70
	Core course–I Practical		Descriptive Statistics Lab	2	30
	Core course–II	STAT01C02	Probability and Probability Distributions-I	5	80
	Core course–II Tutorial		Tutorial	1	20
	Generic Elective–1	STAT01GE01	Any one from the List of **Generic Electives /Interdisciplinary Courses by** other Subjects	4/5	70/80
	Generic Elective–1 Practical/ Tutorial		Practical/Tutorial	2/1	30/20

Semester	Course Name	Paper Code	Course Detail	Credits	Marks
II	Ability Enhancement Compulsory Course–II	STAT02AEC02	English Communication / Environmental Science	4	100
	Core course–III	STAT02C03	Algebra	4	70
	Core course–III Practical		Algebra Lab	2	30
	Core course–IV	STAT02C04	Probability and Probability Distributions-II	4	70
	Core course–IV Practical		Probability and Probability Distributions-II Lab	2	30
	Generic Elective–2	STAT02GE02	Any one from the List of **Generic Electives /Interdisciplinary Courses** from other Subjects	4/5	70/80
	Generic Elective–2 Practical/ Tutorial		Practical/ Tutorial	2/1	30/20
III	Core course–V	STAT03C05	Mathematical Analysis and Calculus	5	80
	Core course–V Tutorial		Tutorial	1	20
	Core course–VI	STAT03C06	Sampling Distributions	4	70
	Core course – VI Practical		Sampling Distributions Lab	2	30
	Core course–VII	STAT03C07	Statistical Computing Using C/C++	4	70
	Core course–VII Practical		Statistical Computing Using C/C++ Lab	2	30
	Skill Enhancement Course–1	STAT03SEE01	Any one from the List of **Skill Enhancement Electives (SEE) meant for semester 3.**	4	100
	Generic Elective–3	STAT03GE03	Any one from the List of **Generic Electives /Interdisciplinary Courses** from other Subjects	4/5	70/80
	Generic Elective–3 Practical/ Tutorial		Practical/ Tutorial	2/1	30/20
IV	Core course–VIII	STAT04C08	Survey Sampling & Indian Official Statistics	4	70
	Core course–VIII Practical		Survey Sampling & Indian Official Statistics Lab	2	30

	Core course–IX	STAT04C09	Statistical Quality Control and Demography	4	70
	Core course–IX Practical		Statistical Quality Control and Demography Lab	2	30
	Core course–X	STAT04C10	Statistical Inference	4	70
	Core course–X Practical		Statistical Inference Lab	2	30
	SkillEnhancement Course-2	STAT04SEE02	Any one from the List of **Skill Enhancement Electives (SEE) meant for semester 4.**	4	100
	Generic Elective–4	STAT04GE04	Any one from the List of **Generic Electives /Interdisciplinary Courses** from other Subjects	4/5	70/80
	Generic Elective–4 Practical/ Tutorial		Practical/ Tutorial	2/1	30/20

Semester	Course Name	Paper Code	Course Detail	Credits	Marks
V	Core course–XI	STAT05C11	Multivariate Analysis and Nonparametric Methods	4	70
	Core course–XI Practical		Multivariate Analysis and Nonparametric Methods Lab	2	30
	Core course–XII	STAT05C12	Linear Models	4	70
	Core course–XII Practical		Linear Models Lab	2	30
	Discipline Specific Elective–1	STAT05DSE01	Any one from the List of **Discipline Specific Electives (DSE)**	4/5	70/80
	Discipline Specific Elective–1 Practical/ Tutorial		Practical/ Tutorial	2/1	30/20
	Discipline Specific Elective–2	STAT05DSE02	Any one from the List of **Discipline Specific Electives (DSE)**	4/5	70/80
	Discipline Specific Elective–		Practical/ Tutorial	2/1	30/20

	2 Practical/ Tutorial				
VI	Core course–XIII	STAT06C13	Design of Experiments	4	70
	Core course–XIII Practical		Design of Experiments Lab	2	30
	Core course–XIV	STAT06C14	Time Series Analysis and Index Numbers	4	70
	Core course–XIV Practical		Time Series Analysis and Index Numbers Lab	2	30
	Discipline Specific Elective–3	STAT06DSE03	Any one from the List of **Discipline Specific Electives (DSE)**	4/5	70/80
	Discipline Specific Elective–3 Practical/ Tutorial		Practical/ Tutorial	2/1	30/20
	Discipline Specific Elective–4	STAT06DSE04	Any one from the List of **Discipline Specific Electives (DSE)**	4/5	70/80
	Discipline Specific Elective–4 Practical/ Tutorial		Practical/ Tutorial	2/1	30/20
Total Marks					2600

[No Paper can be opted for more than once in the Sixth Semester of B.Sc. Examinations.]

N.B :-

1. **The lecture hours calculation in all the papers include both theory and practical/ tutorial classes.**
2. **Use of suitable software such as MS-EXCEL / MINITAB / SPSS or similar others, depending on the availability of faculty and resources for all the core practical courses.**

3. Some Definitions

Programme	A range of learning experiences offered to students in a formal manner over a period of one-to-four years leading to certificates/ diplomas/ degrees. Examples: BA (Economics) BSc (Physics). All possible formal degree Programmes are identified by UGC
Programme Options	A range of courses offered to students to choose at various levels leading to degrees/ diplomas/ certificates.
Programme Outcomes (POs)	Programme Outcomes (POs) are what knowledge, skills and attitudes a graduate should have at the time of graduation. While no agency has formally defined the POs of General Higher Education 3-year degree Programmes in India, POs of all professional Programmes in engineering and other areas are identified at national level by the concerned accrediting agency. POs are not specific to a discipline.
Programme Specific Outcomes (PSOs) in B.Sc. (Hons.) Statistics	The student graduating with the Degree B.Sc. (Honours) Statistics should be able to 1. use skills in Statistics and its related areas of technology for collection data and tackling Statistics related problems and identifying and applying appropriate principles and methodologies to solve a wide range of problems associated with Statistics. 2. acquire (i) a fundamental/systematic or coherent understanding of the academic field of Statistics, its different learning areas and applications in Medical Statistics, Actuarial Statistics, Agricultural Statistics, Geo-Statistics, Financial Statistics, Population Statistics, Financial Econometrics, Clinical Trials and Epidemiology, Queuing Theory, Stochastic Processes, etc., (ii) procedural knowledge that creates different types of professionals related to the disciplinary/subject area of Statistics, including professionals engaged in research and development, teaching and government/public service; (iii) skills in areas related to one's specialization within the disciplinary/subject area of Statistics and current and emerging developments in the field of Statistics. 3. Recognize the importance of statistical modelling, simulation and computing, and the role of approximation and mathematical approaches to analyze the real world problems. 4. Plan and execute Statistics related experiments or investigations, analyze and interpret data/ information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose-written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories of Statistics.

	5. Demonstrate relevant generic skills and global competencies such as (i) problem-solving skills that are required to solve different types of Statistics related problems with well-defined solutions, and tackle open-ended problems that belong to the disciplinary-area boundaries; (ii) investigative skills, including skills of independent investigation of Statistics related issues and problems; (iii) communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences of technical or popular nature; (iv) analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to Statistics and ability to translate them with popular language when needed; (v) ICT skills; (vi) personal skills such as the ability to work both independently and in a group. 6. Demonstrate professional behaviour such as (i) being objective, unbiased and truthful in all aspects of work and avoiding unethical, irrational behaviour such as fabricating, falsifying or misrepresenting data or committing plagiarism; (ii) the ability to identify the potential ethical issues in work-related situations; (iii) appreciation of intellectual property, environmental and sustainability issues; and (iv) promoting safe learning and working environment.
Course	A course is a unit of 2 to 6 credits in a formal program. A 3-credit course will have three classroom sessions of one-hour duration during each week for the entire semester. Example: Program: BA Economics; Course: Kerala Economy; Credits: 3:0:1
Course Outcomes (COs)	COs are statements that describe what students should be able to do at the end of a course. They can be 6±2 for courses with 2 to 4 credits, and 8±2 for courses with 5 to 6 credits.

4.

Aims and Objectives:

The aims of this programme are to build upon the basic knowledge of Statistics, demonstrate the ability to use skills in Statistics and its related areas of technology for formulating and tackling related problems and identifying and applying appropriate principles and methodologies to solve a wide range of problems associated with Statistics.

Program Outcomes

On completion of this course, students should

A. gain fundamental knowledge on various aspects of

(i) fundamental, systematic and coherent understanding of the academic field of Statistics, its different learning areas and applications in Medical Statistics, Actuarial Statistics, Agricultural Statistics, Geo-Statistics, Financial Statistics, Population Statistics, Financial Econometrics, Clinical Trials and Epidemiology, Queuing Theory, Stochastic Processes, etc.,

(ii) procedural knowledge that creates different types of professionals related to the disciplinary/subject area of Statistics, including professionals engaged in research and development, teaching and government/public service;

(iii) skills in areas related to one's specialization area within the disciplinary/subject area of Statistics and current and emerging developments in the field of Statistics.

(iv) problem-solving skills that are required to solve different types of Statistics related problems with well-defined solutions, and tackle open-ended problems that belong to the disciplinary-area boundaries;

(v) investigative skills, including skills of independent investigation of Statistics related issues and problems;

(iii) communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences of technical or popular nature;

(vi) analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to Statistics and ability to translate them with popular language when needed;

(vii) ICT skills;

(viii) personal skills such as the ability to work both independently and in a group.

B. demonstrate professional behaviour such as

(ix) being objective, unbiased and truthful in all aspects of work and avoiding unethical, irrational behaviour such as fabricating, falsifying or misrepresenting data or committing plagiarism;

(x) the ability to identify the potential ethical issues in work-related situations;

(xi) appreciation of intellectual property, environmental and sustainability issues; and

(xii) promoting safe learning and working environment.

Program Specific Outcomes

The students should be able to make rational decisions about their career in fields such as academics, recognize the importance of statistical modelling simulation and computing, and the role of approximation and mathematical approaches to analyse the real-world problems.

Teaching-learning Process

Teaching will include lectures (online or offline), hands-on training, laboratory dissertation. Doubt-clearing classes/sessions are arranges in each semester. Teachers with expertise in a certain field will teach that module by having a proper idea of

(i) the curriculum, assessing learning needs, and establishing specific learning objectives. Teachers will be in continuous interaction with the students so that the various teaching and learning strategies can be implemented, while maintaining the students' motivation and curiosity about the subjects. Special care will be taken for underperforming students to make them feel confident about the subject.

(ii) plan and execute Statistics related experiments or investigations, analyse and interpret data/information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose-written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories of Statistics.

Teaching and Mode of Assessment

Evaluations will be in two parts – internal assessment and final assessment/examination. Both time-bound written and oral examinations will be held. The presentations and interaction during presentations will be evaluated in an objective manner. Class tests, quizzes and group discussion will be conducted for continuous assessment. Regular performance for the laboratory courses will also be assessed in an objective manner.

5.

Detailed Syllabus of CBCS Courses in B.Sc. (Honours) Statistics

Core Papers in Statistics Honours

Semester	**ONE**
Paper Number	**STAT01C01**
Paper Title	**Descriptive Statistics**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire (a) knowledge on brief history of the subject Statistics and its interplay with other disciplines. (b) knowledge of various types of data, handling the data and of its scope and importance in various areas such as Medical, Engineering, Agricultural and Social Sciences etc. (c) skill to organise data, graphical displays and evaluation of summary measures such as measures of central tendency and dispersion etc. (d) knowledge of data reflecting quality characteristics including concepts of independence and association between two attributes.
Syllabus	**Unit 1** Introduction: Nature of Statistics, Uses of Statistics, Statistics in relation to other disciplines, Abuses of Statistics. Types of Data: Concepts of population and sample, quantitative and qualitative data, cross-sectional and time-series data, discrete and continuous data. Different types of scales: Nominal, ordinal, interval and ratio. Collection and Scrutiny of Data: Primary data – designing a questionnaire and a schedule, checking its consistency. Secondary data – its major sources. Complete enumeration. Presentation of data: Construction of Tables with one or more factors of classification, diagrammatic representations, frequency distributions and cumulative frequency distributions and their graphical representations, stem and leaf displays. **30L**
	Unit 2 Measures of Central Tendency: Mean, Median, Mode. Measures of Dispersion: range, mean deviation, standard deviation, coefficient of variation, Gini's Coefficient, Lorenz Curve. Moments, Sheppard's corrections (without proof), skewness and kurtosis, Quantiles and measures based on them, Liapunov's inequality and other inequalities related to measures of skewness and kurtosis.Box Plot, Outlier Detection. Quantile-Quantile Plot. **40L**
	Unit 3 Bivariate data: Definition, scatter diagram, simple correlation, linear regression, principle of least squares, Correlation Index, Correlation Ratio. Intra-class correlation coefficient.

	Spearman's Rank correlation and Kendall's Tau (including tie cases). **30L**
	Unit 4 Analysis of Categorical Data: Contingency table, association of attributes and different measures, odds ratio, Pearson's measure, Goodman-Kruskal's Gamma **28L**
List of Practicals	Graphical representation of data. Problems based on measures of central tendency. Problems based on measures of dispersion. Problems based on combined mean and variance and coefficient of variation. Problems based on moments, skewness and kurtosis. Fitting of polynomials, exponential curves. Karl Pearson correlation coefficient. Correlation coefficient for a bivariate frequency distribution. Lines of regression, angle between lines and estimated values of variables. Correlation ratio and correlation index. Rank correlation with and without ties. Computation of intra class correlation coefficient Problems on measures of association.
Reading/Reference Lists	Freedman, Pisani, Purves: Statistics. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edn. The World Press, Kolkata. Yule G.U. and Kendall M.G. : An Introduction to the Theory of Statistics. Snedecor & Cochran : Statistical Methods (6th ed). Croxton F.E., Cowden D.J. & Klein : Applied General Statistics. Moore, D.S & Notz. W.I.: Statistics – Concepts and Controversies. Siegel, A.F. & Morgan, C.J.: Statistics and Data Analysis – An Introduction. Wallis F.E. & Roberts H.V. : Statistics- a new approach. Lewis-Beck M.S. (ed.) : Regression Analysis. A. Agresti : Analysis of Ordinal Categorical Data.

Semester	**ONE**
Paper Number	**STAT01C02**
Paper Title	**Probability and Probability Distributions I**
No. of Credits	**6**
No. of Classes	Theory : 5 Tutorial : 1
Course Learning	Students will acquire

Outcomes	(a) ability to distinguish between random and non-random experiments. (b) knowledge to conceptualise the probabilities of events including frequentist and axiomatic approach, notion of conditional probability including the concept of Bayes' Theorem, independence of events. (c) knowledge related to concept of discrete and continuous random variables, their probability distributions including expectation and moments, generating functions. (d) knowledge of bivariate probability distributions, sum-law and product-law of expectation.
Syllabus	**Unit 1** Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical. Limitations of Classical definition. Probability of union and intersection of events, Probability of occurrence of exactly m and at least m events out of n events, Examples based on classical approach and repeated trials, Kolmogorov's Axiomatic definition. **30L**
	Unit 2 Conditional Probability, laws of addition and multiplication, theorem of total probability, Bayes' theorem and its applications, independent events. **15L**
	Unit 3 Random variables, distribution function and properties, p.m.f., p.d.f., illustrations and properties of random variables. Mathematical Expectation and properties. Probability generating function. Moments, Dispersion, Skewness, Kurtosis and Quantiles. Cauchy-Swartz Inequality, inequalities related to moments and measures of skewness and kurtosis. Moment generating function, Cumulant generating function and Characteristic function. Uniqueness and inversion theorems (without proof) along with applications. Gambler's ruin problem. **40L**
	Unit 4 Two dimensional random variables: discrete type, joint, marginal and conditional p.m.f and c.d.f., statement of properties of c.d.f, independence of variables, Sum-law and Product-law of expectation, trinomial distribution. **11L**
List of Practicals	Tutorial Only
Reading/Reference Lists	S.M. Ross : A First Course in Probability. Feller W.: An Introduction to Probability Theory & its Applications. Anirban DasGupta: Fundamentals of Probability- A First Course. K.L. Chung : Elementary Probability Theory with Stochastic Process. Rohatgi V.K. (1984): An Intro. to Probability Theory & Math. Statistics. Chandra T.K. & Chatterjee D. : A First Course in Probability. Goon A.M., Gupta M.K. & Dasgupta B.: An Outline of Statistical Theory (Vol-1). Hoel P.J., Port S.C. & Stone C.J.: Introduction to Probability Theory (Vol-1). Cramer H. : The Elements of Probability Theory. Parzen E. : Modern Probability Theory and its Applications. Uspensky J.V. : Introduction to Mathematical Probability. Cacoullos T. : Exercises in Probability. Pitman J. : Probability. Stirzaker D. : Elementary Probability. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia. Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.

Semester	**TWO**
Paper Number	**STAT02C03**
Paper Title	**Algebra**
No. of Credits	**6**
No. of classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) vector space, linear dependence and independence of vectors, spanning vector space, projection of vector. (b) matrices, trace, Determinant, Adjoint and inverse of a matrix, product of determinants, related results. (c) theory of equations, generalised inverse of matrix; quadratic forms, linear transformations. (d) characteristic roots, characteristic vectors, and different related methods. (e) Inner Product and Norm. (f) applications of Linear Algebra in Statistics as the foundation to the courses like Multivariate Analysis and Linear Models.
Syllabus	**Unit 1** Real vectors (generalization of co-ordinates), Angle and Norm of vectors, Orthogonality and Gram-Schmidt Orthogonalization Process. Axiomatic Approach and examples. Subspaces, intersection and sum of subspaces. Span of a set, Linear dependence and independence, dimension and basis, dimension theorem. Direct Sum and Complement subspace, Orthogonal Projection of a vector. **30L**
	Unit 2 Algebra of matrices, theorems related to triangular, symmetric and skew symmetric matrices, idempotent matrices, orthogonal matrices, singular and non-singular matrices and their properties. Trace of a matrix, Determinant, Adjoint and inverse of a matrix and related properties. Product of determinants, inverse of a matrix. Rank of a matrix, row-rank, column-rank, standard theorems on ranks, rank of the sum and the product of two matrices. Rank factorization and Sylvester's Inequality. Partitioning of matrices and determinant and inverse of partitioned matrices. Elementary transformations, Echelon form and Normal form. **35L**
	Unit 3 System of homogeneous and non-homogeneous linear equations, Projection Matrix and application to least square method. Generalized inverse, Moore-Penrose inverse. Quadratic forms: Classification & canonical reduction. Linear transformations. **30L**
	Unit 4 Characteristic roots and Characteristic vector, Properties of characteristic roots (symmetric and general matrices). Diagonalization of matrices, Spectral Decomposition, and Singular value decomposition. Power method, Cayley Hamilton theorem, Extrema of Quadratic forms. General concepts of Inner Product and Norm (Brief discussion), Applications of Linear Algebra in Statistics. **33L**
List of Practical	Linear independence and dependence.

	Orthogonality and Gram-Schmidt Orthogonalization Process. Basis and Dimension. Basis of sum, intersection and complement of subspaces. Projection of vectors on a subspace. Determinant of a matrix. Inverse of matrix. Rank and Rank factorization of matrices. Elementary transformations. Solutions of system of linear equations. Finding g-inverse of a matrix. Problems on quadratic forms. Problems relayed to characteristic roots and vectors. Power method of finding characteristic roots. Problems related to linear transformations.
Reading/Reference Lists	Hadley G. : Linear Algebra. Rao A.R. & Bhimasankaram P. : Linear Algebra. Searle S.R. : Matrix Algebra – useful for Statistics. Rao C.R. : Linear Statistical Inference & its Applications. Hoffman K. & Kunze R. : Linear Algebra. Goon A.M. : Vectors and Matrices.

Semester	**TWO**
Paper Number	**STAT02C04**
Paper Title	**Probability and Probability Distributions II**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	This is an advanced level course designed to provide knowledge to the students on (a) some discrete and continuous probability distributions and their properties. (b) some probability inequalities. (c) some scaling methods. (d) bivariate normal distribution with its properties. (e) intuitive explanation of which of these theoretical models are applicable for what kind of datasets. (f) law of large numbers, Central Limit theorems.
Syllabus	**Unit 1** Standard discrete probability distributions: Binomial, Poisson, geometric, negative binomial, hypergeometric, uniform. Standard continuous probability distributions: uniform, normal, exponential, Cauchy, beta, gamma, lognormal, logistic, double exponential and Pareto along with their properties and limiting/approximation cases. Truncated distributions. **40L**
	Unit 2 Probability Inequalities (Univariate Cases) : Markov's & Chebyshev's (one- and two- sided)

	inequalities, Jensen's Inequality, Holder's Inequality, Minkowski's Inequality, Cr Inequality etc. Scaling methods : Z, Percentile, Thurstone, Equivalent scaling procedures. **23L**
	Unit 3 Review of Bivariate c.d.f and p.d.f. and generating functions in continuous case. Marginal and Conditional distributions, Independence, Conditional Expectation, Correlation and Regression. Theorems on sum and product of expectations of random variables. Bivariate Normal Distribution (BVN): p.d.f., properties, marginal and conditional distribution. **35L**
	Unit 4 Limit laws: Sequence of random variables, convergence in probability, almost sure convergence, convergence in mean square and convergence in distribution and their interrelations, W.L.L.N., S.L.L.N and their applications, De-Moivre Laplace Limit theorem, Statement of Central Limit Theorem (C.L.T.) for i.i.d. variates, applications of C.L.T. **30L**
List of Practicals	Fitting of binomial distribution for given n and p. Fitting of binomial distribution after computing mean and variance. Fitting of Poisson distribution for given value of lambda. Fitting of Poisson distribution after computing mean. Fitting of negative binomial. Fitting of suitable distribution. Application problem based on binomial distribution. Application problem based on Poisson distribution. Application problem based on negative binomial distribution. Problems based on are property of normal distribution. To find the ordinate for a given area for normal distribution. Application based problems using normal distribution. Fitting of normal distribution when parameters are given . Fitting of normal distribution when parameters are not given. Fitting of some other continuous distributions. Scaling of scores. Fitting of truncated distributions.
Reading/Reference Lists	S.M. Ross : A First Course in Probability. Feller W.: An Introduction to Probability Theory & its Applications. Anirban DasGupta: Fundamentals of Probability- A First Course. K.L. Chung : Elementary Probability Theory with Stochastic Process. Rohatgi V.K. (1984): An Intro. to Probability Theory & Math. Statistics. Chandra T.K. & Chatterjee D. : A First Course in Probability. Goon A.M., Gupta M.K. & Dasgupta B.: An Outline of Statistical Theory (Vol-1). Hoel P.J., Port S.C.&Stone C.J.: Introduction to Probability Theory (Vol-1). Cramer H. : The Elements of Probability Theory. Parzen E. : Modern Probability Theory and its Applications. Uspensky J.V. : Introduction to Mathematical Probability. Cacoullos T. : Exercises in Probability. Pitman J. : Probability. Stirzaker D. : Elementary Probability. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia. Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.

Semester	**THREE**
Paper Number	**STAT03C05**
Paper Title	**Mathematical Analysis and Calculus**
No. of Credits	**6**
No. of Classes	Theory : 5 Tutorial : 1
Course Learning Outcomes	At the end of the course, a student will have knowledge on (a) representation of real numbers, identifying sequences of real numbers and their properties; function and its properties. (b) series of real numbers and different tests to study their convergence/divergence. (c) limit and its properties including related theorems. (d) Reimann Integration , improper integration, series and sequence of functions. (e) functions of two variables, partial derivative, maxima, minima, multiple integration and, transformation of variables and jacobian of transformation.
Syllabus	**Unit 1** Representation of real numbers as points on a line, Algebraic, Field Structure, Order Structure and Completeness properties of **R** (Concepts only) , Archemedian Property , Bounded and unbounded sets, neighbourhood of a point, Supremum and infimum, Topological properties of real line. Functions, Countable, Uncountable sets and Uncountability of **R**. Sequences and their convergence, Subsequences, monotonic sequences, bounded sequences, squeeze theorem Limits of some special sequences such as $r^n, \left(1+\frac{1}{n}\right)^n$ and $n^{\frac{1}{n}}$, Concept of limsup and liminf. Infinite series, positive termed series and their convergence, Comparison test, ratio test and root test. Absolute convergence of series, Leibnitz's test for the convergence of alternating series, Conditional convergence, Rearrangement and Riemann's Theorem (Statement only). **31L**
	Unit 2 Review of limit, Concepts of o and O. Continuity and Uniform Continuity and boundedness of a function. Differentiability, Indeterminate form, L' Hospital's rule. Darboux Theorem, Rolle's and Lagrange's Mean Value theorems. Taylor's theorem with Lagrange's and Cauchy's form of remainder(without proof). Taylor's and Maclaurin series expansions of sinx, cosx, e^x, $(1+x)^n$, log(1+x). Maxima and Minima of Functions. Successive Differentiation. **25L**
	Unit 3 Reimann Integration of Real valued Functions. Fundamental Theorem of Integral Calculus. Improper Integral, Convergence of Integrals, Simple tests. Beta and Gamma functions: properties and relationship between them. Sequence and series of functions: Pointwise & Uniform convergence. Simple tests, Properties of Uniformly convergent functions. Power series. Sequences and Series of functions. **25L**

	Unit 4 Functions of two variables and Partial Derivatives. Maxima and Minima of such Functions. Constrained Maximization and minimization, use of Lagrange Multiplier. Double Integral (intuitive-graphical approach), Multiple Integration, change of order of integration, transformation of variables and Jacobians (statement of relevant theorems and their uses). **15L**
List of Practicals	Tutorials only
Reading/Reference Lists	R G Bartle, Sherbert D R.: Introduction to Real Analysis. Apostol, T.M. : Mathematical Analysis. Malik, S.C. & Arora, S. : Mathematical Analysis. Kumaresan, S:A Basic Course in Real Analysis. Chakraborty, Arnab (2014): Real Analysis, volumes 1,2,3, second edition. Sarat Book House.

Semester	**THREE**
Paper Number	**STAT03C06**
Paper Title	**Sampling Distributions**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	A student will be able to understand (a) The notion of sampling distribution of a statistic. (b) Derivation of some exact sampling distributions of statistics like Chi-square, t, F etc. (c) Sampling distributions of statistics related to samples from bivariate normal distribution(s). (d) The notion of order statistics and related sampling distributions. (e) The importance of sampling distributions in Statistical Inference. The basics of Testing of Hypotheses and confidence intervals. (f) The basic principle underlying tests of significance with applications.
Syllabus	**Unit 1** Functions of Random Vectors (univariate distributions): Jacobian, Polar transformations and Orthogonal Transformations. Derivation of the sampling distribution of sample mean and variance for a normal population, standard errors of sample mean, sample variance and sample proportion. Exact sampling distribution: Definition and derivation of p.d.f. of χ^2 with n degrees of freedom (d.f.), nature of p.d.f. curve for different degrees of freedom, mean, variance, m.g.f., additive property of χ^2 distribution. Exact sampling distributions: Student's and Fisher's t-distributions, Derivation of its p.d.f., nature of probability curve with different degrees of freedom, mean, variance and limiting form of t distribution. Snedecor's F-distribution: Derivation of p.d.f., nature of p.d.f. curve with different degrees of freedom, mean, variance. Distribution of 1/F (n1, n2). Relationship between t, F and χ^2 distributions. **50L**
	Unit 2

	Sampling distribution based on BVN: Distribution of sample correlation coefficient in the null case, regression coefficients and other related results with non-stochastic covariate. Order Statistics: Introduction, distribution of the rth order statistic, smallest and largest order statistics. Joint distribution of rth and sth order statistics, distribution of sample median and sample range. **25L**
	Unit 3 Problems of Statistical Inference: Population & parameter, random sample & statistic, Point and Interval Estimation, Confidence level, Testing of Hypothesis, Null and alternative hypotheses, level of significance, Type I and Type II errors, their probabilities and critical region. **15L**
	Unit 4 Exact tests and confidence intervals: classical and p-value approaches related to Binomial proportion(s), Poisson mean(s), Univariate Normal mean(s), standard deviation(s). Standard tests related to Bivariate normal parameters. **38L**
List of Practicals	Testing of significance for single proportion and difference of two proportions. Testing of significance for single Poisson mean and difference of means of two independent Poisson distributions. Testing of significance and confidence intervals for single mean and difference of two means and paired tests. Testing if the population variance has a specific value and its confidence intervals. Testing of significance and confidence intervals of correlation coefficient. Testing of equality of population variances for two independent normal populations and related confidence intervals. Testing of ratio of variances for bivariate normal population and related confidence interval. Tests related to regression and related confidence intervals.
Reading/Reference Lists	Rohatgi, V. K. and Saleh, A.K.M.E. (2015): An Introduction to Probability and Statistics, Third Edn,Wiley, NJ. Mukhopadhay, N.: Probability and Statistical Inference. Goon A.M., Gupta M.K. & Dasgupta B.: An Outline of Statistical Theory (Vol-1). Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edn. The World Press, Kolkata. Mood, A.M., Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn. (Reprint).Tata McGraw-Hill Pub. Co. Ltd. Casella , G. and Berger R.L. (2002).: Statistical Inference, 2nd Edn, Thomson Learning. Bhattacharya GK & Johnson R. A. : Concepts & Methods of Statistics.

Semester	**THREE**
Paper Number	**STAT03C07**
Paper Title	**Statistical Computing Using C/C++**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4

Course Learning Outcomes	Students will acquire knowledge of (a) the basic structure of C programming language with different data types. (b) Operations, loop structures and their uses. (c) conditional statements, arrays and their uses. (d) Functions, multi-function program, processor, pointer. (e) the basic ways of handling file in C, usage of C programming in some selected areas of Statistics. (f) Preliminaries of numerical analysis – interpolation, numerical integration and solution of transcendental equations. (g) Use of C programmes to perform basic statistical analysis on several real datasets.
Syllabus	**Unit 1** Components, basic structure programming, character set, C/C++ tokens, Keywords and Identifiers and execution of a C/C++ program. Data types: Basic data types, Enumerated data types, derived data types. Constants and variables: declaration and assignment of variables, Symbolic Constants, overflow and underflow of data. Operators and Expressions: Arithmetic, relational, logical, assignment, increment/decrement, operators, precedence of operators in arithmetic, relational and logical expression. Implicit and explicit type conversions in expressions, library functions. Managing input and output operations: reading and printing formatted and unformatted data. Decision making and branching - if…else, nesting of if…else, else if ladder, switch, conditional (?) operator. Looping in C/C++: for, nested for, while, do…while, and jumps in and out of loops. Arrays: Declaration and initialization of one-dim and two-dim arrays. Character arrays and strings: Declaring and initializing string variables, reading and writing strings from Terminal (using scanf and printf only). **30L**
	Unit 2 User-defined functions: A multi-function program using user-defined functions, definition of functions, return values and their types, function prototypes and calls. Category of Functions : no arguments and no return values, arguments but no return values , arguments with return values, no arguments but returns a value, functions that return multiple values. Recursion function. Passing arrays to functions, Storage class of Variables. Pointers: Declaration and initialization of pointer variables, accessing the address of a variable, accessing a variable through its pointer, pointer expressions, pointer increments/decrement and scale factor. Pointers and arrays, arrays of pointers, pointers as function arguments, functions returning pointers Structure: Definition and declaring, initialization, accessing structure members, copying and comparison of structure variables, array of structures, structure pointers. Dynamic memory allocation functions: malloc, calloc and free. Pre-processors: Macro substitution, macro with argument File inclusion in C/C++: Defining and opening a file (only r, w and a modes), closing a file, I/O operations on files-fscanf and fprintf functions. **30L**
	Unit 3 Drawing of random sample from standard univariate discrete and continuous distributions, cdf inversion method, box-muller transformation, polar transformation. Drawing of random samples from mixture distribution and bivariate normal (conditional distribution approach). Acceptance rejection sampling. Monte Carlo Integration, Variance Reduction techniques. **35L**
	Unit 4 Numerical Analysis: Polynomials and Difference Tables. Approximation of functions and Weierstrass Theorem (statement). Lagrange and Newton formulae for Interpolation. Trapezoidal and Simpson's 1/3 Rules for approximations of definite integrals. Approximate solutions of Numerical Equations by Fixed-point Iteration and Newton-Raphson methods.

	Conditions of convergence. **33L**
List of Practicals	Roots of a quadratic equation (with imaginary roots also). Sorting of an array and hence finding median. Mean, Median and Mode of a Grouped Frequency Data. Variance and coefficient of variation of a Grouped Frequency Data. Preparing a frequency table. Value of n factorial using recursion. Random number generation from uniform, exponential, calculate sample mean and variance and compare with population parameters. Matrix addition, subtraction, multiplication, Transpose and Trace. Fitting of Binomial, Poisson distribution. Compute ranks and then calculate rank correlation (without tied ranks). Fitting of lines of regression. Numerical methods: Solving one-variable equations using Newton-Raphson method. Trapezoidal rule for numerical integration. Solving a linear system of equation. Generation of random samples from standard discrete and continuous distributions. Generation of random samples from mixture distributions. Generation of random samples from bivariate normal distribution. General of random samples by acceptance rejection method. Monte Carlo integration and related techniques.
Reading/Reference Lists	Kernighan, B.W. and Ritchie, D.(1988): C Programming Language,2ndEdition, Prentice Hall. Balagurusamy, E. (2011): Programming in ANSI C, 6th Edition Tata McGraw Hill. Ross, S: Simulation. Scarborough, J.B. (1966): Numerical Mathematical Analysis. Oxford and IBH Publishing. Mollah, S. A. : Numerical Analysis & Computational Procedures. Atkinson K. : Elementary Numerical Analysis. Sastry S.S.: Introductory Methods of Numerical Analysis. Hildebrand F.B. : Introduction to Numerical Analysis.

Semester	**FOUR**
Paper Number	**STAT04C08**
Paper Title	**Survey Sampling and Indian Official Statistics**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) Population and sample, probability sampling. (b) Different sampling schemes and situations where these are applicable. (c) introducing auxiliary variable in the improvement of estimation procedures under certain situations. (d) sources of official statistics, mechanisms of collection of official data in India under MoSPI. (e) national income.
Syllabus	**Unit 1**

	Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, definition and procedure of selecting a sample, estimates of: population mean, total and proportion, variances of these estimates, estimates of their variances and sample size determination. **32L**
	Unit 2 Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision, post stratification and its performance. Systematic Sampling: Technique, estimates of population mean and total, variances of these estimates (N=n x k). Comparison of systematic sampling with SRS and stratified sampling in the presence of linear trend and corrections. **32L**
	Unit 3 Introduction to Ratio and regression methods of estimation, estimation of the population mean and total (for SRS of large size), MSE of these estimates and estimates of these variances, MSE in terms of correlation coefficient for regression method of estimation and their comparison with SRS. Cluster sampling (equal clusters only) estimation of population mean and its variance, comparison (with and without randomly formed clusters). Concept of sub sampling. Two-stage Sampling, Estimation of Population mean and variance of the estimate, Randomized Response Technique: Warner Model. **32L**
	Unit 4 An outline of present official statistical system in India, Methods of collection of official statistics, their reliability and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), Registered General Office and National Statistical Commission. Government of India's Principal publications containing data on the topics such as Agriculture, price, population, industry, finance and employment Consumer price Index, Wholesale price index number and index of industrial production. National Income: Basic idea and a brief description of income, expenditure and production approaches. **32L**
List of Practicals	To select an SRS with and without replacement from finite populations, theoretical populations and given geometrical shapes. For a population of size 5, estimate population mean, population mean square and population variance. Enumerate all possible samples of size 2 by WR and WOR and establish all properties relative to SRS. For SRSWOR, estimate mean, standard error and the sample size. Stratified Sampling: allocation of sample to strata by Proportional and Neyman's methods. Compare the efficiencies of above two methods relative to SRS. Estimation of gain in precision in stratified sampling. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend. Ratio and Regression estimation: Calculate the population mean or total of the population. Calculate mean squares. Compare the efficiencies of ratio and regression estimators relative to SRS. Cluster sampling: estimation of mean or total, variance of the estimate, estimate of intra-class correlation coefficient, efficiency as compared to SRS. Two stage sampling.
Reading/Reference Lists	Cochran, W.G. (1984): Sampling Techniques (3rd Ed.), Wiley Eastern. Sukhatme, P.V., Sukhatme, B.V. Sukhatme, S. Asok, C. (1984). Sampling Theories of Survey

	With Application, IOWA State University Press and Indian Society of Agricultural Statistics. Murthy, M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta. Des Raj and Chandhok P. (1998): Sample Survey Theory, Narosa Publishing House. Goon A.M., Gupta M.K. and Dasgupta B. (2008): Fundamentals of Statistics, Vol-II, World Press. Guide to current Indian Official Statistics, Central Statistical Office, GOI, and New Delhi. http://mospi.nic.in/

Semester	**FOUR**
Paper Number	**STAT04C09**
Paper Title	**Statistical Quality Control and Demography**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) application of statistics in industry. (b) various phases of SQC, quality of the manufactured items. (c) SQC approaches namely Control Charts in Process Control and Sampling Inspection Techniques in Product Control; measure of process capability. (d) study of human population, some of the basic and derived measures. (e) life table and its significance in real life. (f) growth of a population along with methods of estimating and forecasting.
Syllabus	**Unit 1** Definition, dimensions of quality. Quality system and standards: Introduction to ISO quality standards, Quality registration. Statistical Process Control - Seven tools of SPC, chance and assignable Causes of quality variation. Statistical Control Charts- Statistical basis and construction of 3-σ Control charts, Rational Sub-grouping and different control charts. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on control chart. Estimation of process capability. **30L**
	Unit 2 Principle of acceptance sampling plans. Single and Double sampling plan their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Romig's sampling inspection plan tables. **30L**
	Unit 3 Introduction and sources of collecting data on vital statistics, errors in census and registration data. Measurement of population, rate and ratio of vital events. Measurements of Mortality: Crude Death Rate (CDR), Specific Death Rate (SDR), Infant Mortality, Rate (IMR) and Standardized Death Rates. Stationary and Stable population, Central Mortality Rates and Force of Mortality. Life (Mortality) Tables: Assumption, description, construction of Life Tables and Uses of Life Tables. Measurements of Fertility: Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR) and Total Fertility Rate (TFR). **35L**

	Unit 4 Measurement of Population Growth Theory: Crude rates of natural increase, Pearl's Vital Index, Gross Reproduction Rate (GRR) and Net Reproduction Rate (NRR). Population Estimation, Projection and Forecasting: Use of A.P. and G.P. methods for population estimates, Fitting of Logistic curve for population forecasting using Rhode's method. **33L**
List of Practicals	To calculate CDR and ASDR for a given set of data. To find STDR by direct and indirect methods. To construct a complete life table. To fill in the missing entries of a life table. To calculate probabilities of death at pivotal ages and use it to construct abridged life table. using (i) Reed-Merrell method, (ii) Greville's method and (iii) King's method. To calculate CBR, GFR, SFR, TFR for a given set of data. To calculate crude rate of Natural Increase and Pearle's Vital index for a given set of data. Calculate GRR and NRR for a given set of data and compare them. Population Estimation and Projection. Fitting of logistic equation by Rhode`s method. Construction and Interpretation of statistical control charts. X-bar & R chart, X-bar & s-chart, np- chart, p-chart, c-chart, u- chart. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves. Calculation of process capability and comparison of 3-sigma control limits with specification limits.
Reading/Reference Lists	Montgomery, D.C. (2009): Introduction to Statistical Quality control, 6th edition, Wiley India, Pvt Ltd. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol 2, 8th edition, The world Press, Kolkata. Mukhopadhyay, P. (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied(P) Ltd. Montgomery, D.C. and Runger, G.C. (2008): Applied Statistics and Probability for Engineers, 3rd edition reprint, Wiley India Pvt Ltd. Ehrlich, B. Harris (2002): Transactional Six sigma and Lean Servicing, 2nd edition, St Lucie Press. Hoyle, David (1995): ISO Quality systems Handbook, 2nd edition, Butterworth Heinemann Publication. Nagar A.L, Das R.K (1997): Basic statistics, Oxford University Press. Ramakumar R (2002) Technical Demography, New Age.

Semester	**FOUR**
Paper Number	**STAT04C10**
Paper Title	**Statistical Inference**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) a fundamental understanding of Parametric models for developing relevant inferences

	on associated parameters. (b) theory of point estimation and interval estimation and different procedures of estimation. (c) the Cramer-Rao Inequality, Rao Blackwell and Lehmann Scheffe theorems and their applications in obtaining Minimum Variance Unbiased and Minimum Variance Bound estimators. (d) most powerful test and associated derivations. (e) large-sample approaches in estimation and testing of hypothesis with transformation of statistic to stabilise variance.
Syllabus	**Unit 1** Estimation: Concepts of estimation, unbiasedness, sufficiency, consistency and efficiency. Factorization theorem. Complete statistic, Minimum variance unbiased estimator (MVUE), Necessary and Sufficient condition for UMVUE, Rao-Blackwell and Lehmann-Scheffe theorems and their applications. Cramer-Rao inequality (statement and applications) and MVB estimators. Methods of Estimation: Method of moments, method of maximum likelihood estimation, method of least square, method of minimum Chi-square and statements of their properties. **40L**
	Unit 2 Concept of test function and randomized test, Review of level of significance, power and power curve. Most powerful test, uniformly most powerful test, Neyman- Pearson Lemma (statement and proof of sufficiency part only) and its applications to construct uniformly most powerful test, unbiased test (definition only). Likelihood ratio test, properties of likelihood ratio tests (without proof). **35L**
	Unit 3 Confidence intervals, Confidence set, Shortest length confidence interval, Concepts of Uniformly Most Accurate (UMA) confidence sets, relationship with tests of hypotheses. **15L**
	Unit 4 Delta Method, Derivation and uses of large sample standard error of sample moments, Standard deviation, Coefficient of Variation, b_1 & b_2 measures, Correlation coefficient. Asymptotic distribution of sample quantiles. Transformations of Statistics to stabilize variance: derivation and uses of Sin-1, square root. Uses of logarithmic and z-transformations. Large sample tests for binomial proportions, Poisson means (single and two independent samples cases) and correlation coefficients. Large Sample distribution of Pearsonian $\chi 2$ – statistic and its uses. **38L**
List of Practicals	Maximum Likelihood Estimation. Estimation by the method of moments, minimum Chi-square. Most powerful critical region (NP Lemma). Uniformly most powerful critical region. Unbiased critical region. Power curves. Likelihood ratio tests for simple null hypothesis against simple alternative hypothesis. Likelihood ratio tests for simple null hypothesis against composite alternative hypothesis. Asymptotic properties of LR tests. Testing of significance and confidence intervals for single proportion and difference of two proportions using CLT. Testing of significance and confidence intervals for single Poisson mean and difference of two Poisson means using CLT. Testing of significance and confidence intervals concerning sample standard deviation,

	coefficient of variation and correlation coefficient (both single sample and two sample cases). Testing of significance and confidence intervals using variance stabilizing transformations. Determination of the minimum sample size required to achieve normality by sample proportion, mean and standard deviation. Tests for goodness of fit, independence and homogeneity using Pearsonian chi-square statistic.
Reading/Reference Lists	Rohatgi V.K. (1984): An Intro. to Probability Theory & Math. Statistics. Mukhopadhay, N.: Probability and Statistical Inference. Goon A.M., Gupta M.K. & Dasgupta B.: An Outline of Statistical Theory (Vol-2). Casella , G. and Berger R.L. (2002).: Statistical Inference, 2nd Edn, Thomson Learning. Kale, B.K.: A first course in parametric inference, Narosa. Bickel, P.J., Doksum, K.A.: Mathematical Statistics: Basic Ideas and Selected Topics, Volume 1.

Semester	**FIVE**
Paper Number	**STAT05C11**
Paper Title	**Multivariate Analysis and Non-parametric Methods**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) Multivariate data and measures of correlation, regression; random vectors and multivariate probability distribution. (b) Multinomial and Multivariate Normal distributions along with their properties, ellipsoid of concentration. (c) Multivariate Normal distribution- application of multivariate techniques in Principal Component Analysis, Discriminant Analysis and Factor analysis. (d) Different nonparametric tests for location, scale and randomness. use different nonparametric/distribution-free tests when data don't meet the assumptions of parametric test. (e) confidence interval, tolerance and prediction limits.
Syllabus	**Unit 1** Multivariate data – multiple regression, multiple correlation and partial correlation – their properties and related results. Random Vector: Probability mass/density functions, Distribution function, Mean vector & Dispersion matrix, Marginal & Conditional distributions. **25L**
	Unit 2 Multinomial Distribution, Multivariate Normal distribution and its properties Marginal and Conditional Distributions, Ellipsoid of Concentration. Sampling distribution for mean vector and variance- covariance matrix (Statement only) Multiple and partial correlation coefficient and their properties. **35L**

	Unit 3 Applications of Multivariate Analysis: Discriminant Analysis, Principal Components Analysis and Factor Analysis. **23L**
	Unit 4 Nonparametric Tests: Introduction and Concept, Test for randomness based on total number of runs, Empirical distribution function, Kolmogrov Smirnov test, Sign tests and Signed Rank tests, Wilcoxon-Mann-Whitney test, median test, Kruskal-Wallis test, Non-parametric confidence interval, tolerance and prediction limits. **45L**
List of Practicals	*Some practical problems are to be done preferably by using R/ statistical packages.* Multiple Correlation and Regression. Partial Correlation. Discriminant Analysis using R/statistical packages. Principal Component Analysis using R/statistical packages. Factor Analysis using R/statistical packages. Test for randomness based on total number of runs. Kolmogorov Smirnov test for one sample. Sign test. Signed Rank test. Wilcoxon-Mann Whitney U-test. Kruskal-Wallis test. Non-parametric confidence intervals. Non-parametric tests using R/statistical packages.
Reading/Reference Lists	Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rdEdn., John Wiley. Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley. Kshirsagar, A.M. (1972): Multivariate Analysis, 1stEdn. Marcel Dekker. Johnson, R.A. And Wichern, D.W. (2007): Applied Multivariate Analysis, 6thEdn., Pearson & Prentice Hall. Mukhopadhyay, P.: Mathematical Statistics. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002): Fundamentals of Statistics, Vol. 1, 8th Edn. The World Press, Kolkata. Gibbons, J. D. and Chakraborty, S (2003): Nonparametric Statistical Inference. 4th Edition. Marcel Dekker, CRC. Rohatgi, V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2ndEdn. (Reprint) John Wiley and Sons.

Semester	**FIVE**
Paper Number	**STAT05C12**
Paper Title	**Linear Models**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) Gauss-Markov set-up, its identification and use in estimation of parameters. (b) ANOVA models to test the effects of different factors and their interactions.

	(c) testing problems related to regression models. (d) the use of concomitant variables under ANOCOVA models. (e) Regression Diagnostics including quantile-quantile plots.
Syllabus	**Unit 1** Gauss-Markov set-up: Theory of linear estimation, Estimability of linear parametric functions, Method of least squares, Gauss-Markov theorem, Estimation of error variance. Fundamental Theorems on least squares (statements only), General Linear Hypothesis: Testing and confidence interval. **25L**
	Unit 2 Analysis of variance: Definitions of fixed-, random- and mixed-effects models, analysis of variance and covariance in one-way classified data for fixed-effects models, analysis of variance and covariance (with one concomitant variable) in two-way classified data with equal number of observations per cell for fixed-effects models. Analysis of variance one-way classified data for random-effects models. **48L**
	Unit 3 Regression analysis: Estimation and hypothesis testing in case of simple and multiple regression models. Tests for parallelism and identity, linearity of simple regression. Generalization of linear models: Logistic regression for binary responses, Scoring method of estimation, Poisson Regression. **35L**
	Unit 4 Regression Diagnostics: Model checking: Prediction from a fitted model, Violation of usual assumptions concerning normality, Homoscedasticity and collinearity, Diagnostics using quantile-quantile plots. **20L**
List of Practicals	*Some practical problems are to be done preferably by using R/ statistical packages.* Estimability when X is a full rank matrix and not a full rank matrix. Simple linear regression. Multiple regression. Tests for linear hypothesis. Analysis of variance of one-way classified data. Analysis of variance of a two-way classified data with one observation per cell. Analysis of variance of a two-way classified data with equal number of observations per cell. Analysis of covariance of a one-way classified data with one concomitant variable. Analysis of covariance of a two-way classified data with one concomitant variable. Hypothesis testing in case of simple and multiple regression models and related tests. Fitting of linear model using R/ statistical package. Regression diagnostics and checking model assumptions using R/statistical package. Fitting of logistic regression model using R / statistical package.
Reading/Reference Lists	Goon, A.M., Gupta, M.K., and Dasgupta, B. (2002), Fundamental of Statistics, Volume 1 & 2, 8th Edn. The World Press, Kolkata. Scheffe, H, Linear Models. Rao, C.R., Linear Statistical Inference. Stapleton, J. H.: Linear Statistical Models. Mukhopadhyay, P. (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied(P)

	Ltd. Sengupta D. and Jammalamadaka, S. R.: Linear Models, An Integrated Approach. Hocking, R. R.: Methods and Applications of Linear Models. Weisburg, S (2005) Applied Linear Regression (Third edition), Wiley. Wu, C. F. J. and Hamada, M. (2009). Experiments, Analysis and Parameter Design Optimization (Second edition), John Wiley. Renchner, A.C. and Schaalje, G.B. (2008). Linear Models in Statistics (Second edition), John Wiley and Sons.

Semester	**SIX**
Paper Number	**STAT06C13**
Paper Title	**Design of Experiments**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) the basics - Randomization, Replication as essential principles and Local Control as a desirable principle in statistical designing of experiments. (b) carry out one-way and two-way Analysis of Variance. (c) construction of standard designs – CRD, RBD and LSD and apply ANOVA techniques to analyse the data produced thereof. (d) Comparing relative efficiency of one design with respect to another. (e) Analysis of data in case of missing observation. (f) Incomplete Block Designs. (g) Construction un-confounded and confounded Factorial Designs, and analyse the data produced. (h) Construction of Fractional Factorials by creating aliases.
Syllabus	**Unit 1** Role, historical perspective. Terminologies: Experimental error, Basic principles, Uniformity trials, Fertility contour maps, Choice of size and shape of plots and blocks. Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – Layout, Model and Analysis, Relative Efficiencies, Analysis with one missing observation. **45L**
	Unit 2 Balanced Incomplete Block Design (BIBD) – parameters, relationships among its parameters, incidence matrix and its properties, Symmetric BIBD, resolvable BIBD, Affine Resolvable BIBD, Intrablock Analysis, Complementary BIBD, Residual BIBD, Dual BIBD, Derived

	BIBD. **35L**
	Unit 3 Advantages, Notations and Concepts of 2^n factorial experiments – their design and analysis. Total and Partial confounding for 2^n($n \leq 5$) factorial experiments. **35L**
	Unit 4 Construction of one-half and one-quarter fractions of 2^n (n≤5) factorial experiments, Alias structure, Resolution of a design. **23L**
List of Practicals	Analysis of CRD. Analysis of an RBD. Analysis of an LSD. Analysis of an RBD with one missing observation. Analysis of an LSD with one missing observation. Intra Block analysis of a BIBD. Analysis of 2^2 and 2^3 factorial in CRD and RBD. Analysis of 2^2 and 2^3 factorial in LSD. Analysis of a completely confounded two level factorial design in 2 blocks. Analysis of a completely confounded two level factorial design in 4 blocks. Analysis of a partially confounded two level factorial design. Analysis of a single replicate of a 2^n design. Analysis of a fraction of 2^n factorial design.
Reading/Reference Lists	Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8thEdn. World Press, Kolkata. Mukhopadhyay, P. : Applied Statistics. Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House. Dey, A. (1986) : Theory of Block Designs, Wiley Eastern Limited. Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley. Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd. Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley.

Semester	**SIX**
Paper Number	**STAT06C14**
Paper Title	**Time Series Analysis and Index Numbers**
No. of Credits	**6**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) time series data, its applications to various fields and components of time series. (b) fitting and plotting of various growth curves such as modified exponential, Gompertz and logistic curve. (c) fitting of trend by Moving Average method. (d) measurement of Seasonal Indices by Ratio-to-Trend, Ratio-to-Moving Average and Link Relative methods.

	(e) calculation of variance of random component by variate-component method. (f) forecasting by exponential smoothing and short term forecasting methods such as Box Jenkins Method and Bayesian forecasting. (g) weak stationarity, autocorrelation and correlogram. (h) price index numbers, quantity index numbers, measuring formulae, their tests for criteria of index numbers, uses.
Syllabus	**Unit 1** Introduction to time series data, application of time series from various fields. Modelling time series as deterministic function plus IID errors: Components of a time series (trend, cyclical and seasonal patterns, random error) Decomposition of time series. Estimation of trend: free hand curve method, method of moving averages, fitting various mathematical curves and growth curves. Effect of elimination of trend on other components of the time series. Estimation of seasonal component by Method of simple averages, Notions of multiplicative models: ratio to Trend. **35L**
	Unit 2 Introduction to stochastic modelling: Concept of stationarity. Illustration of how a stationary time series may show temporal patterns. Stationarity in mean. Box-Jenkins modelling: Moving-average (MA) process and Autoregressive (AR) process of orders one and two. ACF, PACF and their graphical use in guessing the order of AR and MA processes. Estimation of the parameters of AR (1) and AR (2) using Yule-Walker equations. Introduction to ARMA and ARIMA models. **45L**
	Unit 3 Forecasting: Exponential smoothing methods, Short term forecasting methods: Brown's discounted regression. **15L**
	Unit 4 Index Numbers: Price, Quantity and Value indices. Price Index Numbers: Construction, Uses, Limitations, Tests for index numbers, Various formulae and their comparisons, Chain-Index Numbers. Some Important Indices: Consumer Price Index, Wholesale Price Index and Index of Industrial Production – formulae and uses. **33L**
List of Practicals	*Some practical problems are to be done preferably by using R/ statistical packages.* Plotting a real life time series, and detecting various features (trend, periodic behaviours etc.). Suggested data sets: Sun spot data Dollar-Rupee exchange rates Stock market data Fitting and plotting of mathematical curves: modified exponential curve Gompertz curve Fitting of trend by Moving Average Method. Plotting detrended series. Measurement of Seasonal indices Ratio-to-Moving Average method. Plotting ACF and PACF of a given time series. Using Yule-Walker equation to fit AR (1) and AR (2) models to real life data. Forecasting by short term forecasting methods. Forecasting by exponential smoothing. Calculate price and quantity index numbers using simple and weighted average of price relatives. To calculate the Chain Base index numbers.

	Problems on cost of living index numbers.
Reading/Reference Lists	Gun, Gupta and Dasgupta (2002) Fundamentals of Statistics Vol II, World Press. Cooray TMJA(2008) Applied Time Series, Analysis and forecasting, Narosa Publishing house. Chatfield C (2004) Analysis of Time Series, Chapman & Hall. Cryer, J.D. and Chan, K-S: Time Series Analysis with applications in R. P.Brockwell & R.A.Davis : Introduction to time series and forecasting. Mukhopadhyay P. : Applied Statistics.

Skill Enhancement Elective Papers in Statistics Honours

Elective papers to be offered in a semester will be decided every year solely by the departmental committee. This will be intimated before the commencement of classes in the relevant semester.

Semester	**THREE**
Paper Number	**STAT03SEE1A**
Paper Title	**Data Analysis using Excel and R**
No. of Credits	**4**
No. of Classes	Theory : 0 Practical : 8
Course Learning Outcomes	Students will acquire knowledge of (a) use of Excel, diagrammatic representation, summary measures, logical commands like IF, AND, NOT, OR. (b) codes using R language. (c) Linear congruential and mid-square methods for uniform generator. (d) Inverse transform method for simulating various probability distributions and stochastic models. (e) data base management system with special emphasis on significance of topic to the statisticians. (f) Entity relationship, Relational, Hierarchical and Network Models. (g) Generation of reports using Latex: Suggested Editors – Lyx/ Kile/ Texnic-center.
Syllabus	*This course will review and expand upon core topics in statistics and probability, particularly by initiating the beneficiaries of the course to use of spreadsheet and R.* **Unit 1** Use of Excel: Creating grouped frequency distribution, different diagrammatic representations, Data manipulation : Subsetting a data, sorting, searching and creating new variables, Basic summary measures, Linear regression. Logical commands: IF, AND, NOT, OR etc. **30L**
	Unit 2 Introduction to R: Installation, command line environment, overview of capabilities, brief mention of open source philosophy. R as a calculator: The four basic arithmetic operations. Use of parentheses nesting up to

	arbitrary level. The power operation. Evaluation of simple expressions. Quotient and remainder operations for integers. Standard functions, e.g., sin, cos, exp, log., Different types of numbers in R: Division by zero leading to Infor -Inf. NaN. NA. Use of R scripts, R libraries: what is an r library?, how to load and use a library how to get help- documentation and vignettes. Some useful inbuilt functions: getwd(), setwd(), source(). **16L**
	Unit 3 Variables in R. Creating a vector using c(), seq() and colon operator. Basic operations on vectors. Matrix operations in R: Creation. Basic operations. Extracting submatrices through indexing. Dataframes and Lists, Difference between matrices, dataframes and lists. Loading data from a file: read.table() and read.csv(), creation of new variables, categorisation cut, factor; round, apply. Working with dataframes: accessing by variable names, subsetting, transformation of variables. plot() command, histogram, barplot, boxplot, points, lines, segments, arrows, paste inserting mathematical symbols in a plot, pie diagram. customisation of plot: setting graphical parameters from par(). **44L**
	Unit 4 Basic summary statistics, Usual tests of significance and confidence intervals. Use of table() to create frequency distributions. Linear regression: Estimation, finding predicted values, plotting the regression line on scatterplot. Use of apply() and related functions. Problems on discrete and continuous probability distributions. Generation of reports using Latex: Suggested Editors – Lyx/ Kile/ Texnic-center. Use of R package Knitr/ Markdown to produce reports, Case study using any inbuilt or external dataset to understand and apply the statistical techniques discussed in R and prepare a report. **38L**
Reading/Reference Lists	The R Cookbook, by Paul Teetor. The R Graphics Cookbook, by Winston Chang. Data Manipulation with R, by Phil Spector. The R Inferno, by Patrick Burns (freely available at http://www.burns-stat.com/pages/Tutor/R_inferno.pdf). simpleR, by John Verzani (freely available at https://cran.r-project.org/doc/contrib/Verzani-SimpleR.pdf). Quick R (freely available at https://www.statmethods.net/).

Semester	**THREE**
Paper Number	**STAT03SEE1B**
Paper Title	**Data Analysis using software packages**
No. of Credits	**4**
No. of Classes	Theory : 0 Practical : 8
Course Learning Outcomes	Students will acquire knowledge of (a) loading data, plotting a graph viz. histograms, box plot, stem-leaf, frequency polygon,

	pie chart, ogives, (b) Generating automated reports; correlation and lines of regression. (c) Random number generationion and sampling procedures, curves. Application Problems based on fitting of suitable distribution, Normal probability plot, (d) creating and managing statistical analysis projects, import data, code editing, Basics of statistical inference, p-values and confidence intervals.
Syllabus	*This course will review and expand upon core topics in statistics and probability, particularly by initiating the beneficiaries of the course to at least one of the software packages viz., SPSS, Minitab for statistical computing.* **Unit 1** Learn how to load data, plot a graph viz. histograms (equal class intervals and unequal class intervals), box plot, stem-leaf, frequency polygon, pie chart, ogives with graphical summaries of data. **32L**
	Unit 2 Generate automated reports giving detailed descriptive statistics, correlation and lines of regression.. **32L**
	Unit 3 Random number generation and sampling procedures. Fitting of polynomials and exponential curves. Application Problems based on fitting of suitable distribution, Normal probability plot. **32L**
	Unit 4 Simple analysis and create and manage statistical analysis projects, import data, code editing, Basics of statistical inference in order to understand hypothesis testing and compute p-values and confidence intervals. **32L**
Reading/Reference Lists	Moore, D.S. and McCabe, G.P. and Craig, B.A. (2014): Introduction to the Practice of Statistics, W.H. Freeman. Cunningham, B.J (2012):Using SPSS: An Interactive Hands-on approach

Semester	**FOUR**
Paper Number	**STAT04SEE2A**
Paper Title	**Advanced Statistical Computing using R**
No. of Credits	**4**
No. of Classes	Theory : 0 Practical : 8
Course Learning Outcomes	Students will acquire knowledge of (a) Programming in R: Use of if and ifelse, Loops, writing functions; (b) Debugging, checking compatibility of arguments, print error/warning messages; (c) random number generation, random samples from univariate discrete and continuous probability distributions, Simulation of random variables;

	(d) Monte Carlo integration, sampling, approximating the value of pi ; (e) graphical demonstration of the Law of Large Numbers and Central limit theorem; (f) data manipulation, importing data from the Web, transforming data, merging and reshaping dataframes (g) structured query language (SQL) and queries; SELECT and JOIN. R/SQL translations. Accessing databases through R.
Syllabus	*This course will enable students to learn programming skills in R and use simulation techniques to understand some core concepts of probability and statistics.* *A part of this course also enhances database handling through SQL and R.* **Unit 1** Programming in R: Use of if and ifelse, Loops in R, avoiding iteration with "vectorized" operations and functions, writing functions in R, setting default values of arguments of a function. Debugging and testing, checking compatibility of arguments in function and print error/warning messages. **24L**
	Unit 2 Using the computer for random number generation (treated as a black box). Generation of random samples from univariate discrete and continuous probability distributions, cdf inversion method, box-muller transformation. Simulation of random variables from mixture distribution, simulating bivariate normal random variable (using conditional approach), Acceptance rejection sampling. **22L**
	Unit 3 Simulating random experiments like coin tossing, rolling of a die, card shuffling to illustrate probabilities of different events. Monte Carlo integration, Basic idea of importance sampling. Finding probabilities and moments using simulation. Approximating the value of pi by simulating dart throwing. Approximating the expectation of a given function of a random variable using simulation. Graphical demonstration of the Law of Large Numbers and Central limit theorem. Using simulation to compute the level of significance, power, critical value and p-value of tests. **46L**
	Unit 4 Advance data manipulation in R: Reading and writing non-R formats. Importing data from the Web, Selective access to data, applying the same function to all parts of a data object. Transforming the data, merging dataframes, reshaping dataframes from wide to long or long to wide. Split-apply-combine technique in R, Use of plyr functions. Basic concepts of relational databases; how a database is like an R dataframe. The client/server model. The structured query language (SQL) and queries; SELECT and JOIN. R/SQL translations. Accessing databases through R. **36L**
Reading/Reference Lists	Shonkwiler, Ronald W. and Mendivil, Franklin (2009): Explorations in Monte Carlo Methods (Undergraduate Texts in Mathematics). Carsey, Thomas M. and Harden, Jeffrey J. (2014): Monte Carlo Simulation and Resampling Methods for Social Science. Data Manipulation with R, by Phil Spector. John M. Chambers, Software for Data Analysis: Programming with R. S. Ross : Simulation. Quick R (freely available at https://www.statmethods.net/)

Semester	**FOUR**
Paper Number	**STAT04SEE2B**
Paper Title	**Research Methodology**
No. of Credits	**4**
No. of Classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) providing scientific approaches to develop the domain of human knowledge largely through empirical studies. (b) understanding basic concepts and aspects related to research, data collection, analyses and interpretation. (c) preparing and finalizing research report on some real life situations.
Syllabus	**Unit 1** What is Research? Role of Research in important areas. Characteristics of Scientific Method. Process of research: Stating Hypothesis or Research question, Concepts & Constructs, Units of analysis & characteristics of interest, Independent and Dependent variables, Extraneous or Confounding variables. Measurements and scales of Measurements. Types of research: Qualitative & Quantitative Research, Longitudinal Research, Survey & Experimental Research. **24L**
	Unit 2 Survey Methodology and Data Collection, sampling frames and coverage error, non-response. **24L**
	Unit 3 Review of various techniques for data analysis covered in core statistics papers, techniques of interpretation, precaution in interpretation. **40L**
	Unit 4 Develop a questionnaire, collect survey data pertaining to a research problem (such as gender discriminations in private v/s government sector, unemployment rates, removal of subsidy, impact on service class v/s unorganized sectors), questions and answers in surveys, Internal & External validity, , interpret the results and draw inferences. Formats and presentations of Reports – an overview. **40L**
Reading/Reference Lists	Kothari, C.R. (2009): Research Methodology: Methods and Techniques, 2nd Revised Edition reprint, New Age International Publishers. Kumar, R (2011): Research Methodology: A Step - by - Step Guide for Beginners, SAGE publications. Booth , W.C., Colomb, G.G. and Williams, J. M., The Craft of Research, 3rd edition, University of Chicago Press. Alley, M., The Craft of Scientific Writing, 3rd edition, Springer, 1996.

Discipline Specific Elective Papers in Statistics Honours

Elective papers to be offered in a semester will be decided every year solely by the departmental committee. This will be intimated before the commencement of classes in the relevant semester.

Semester	**FIVE/SIX**
Group	**1**
Paper Number	**01**
Paper Title	**Stochastic Processes and Queuing Theory**
No. of Credits	**6**
No. of classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) Idea of stochastic processes. (b) Markov chains including the notion of transition probability matrix. (c) various other stochastic processes such as generalised Bernoulli process, Poisson process, birth and death processes. (d) queuing theory, finite and infinite system capacity, waiting time distribution. (e) application of these processes in real life problems.
Syllabus	**Unit 1** Stochastic Process: Introduction, Stationary Process. **10L**
	Unit 2 Markov Chains: Definition of Markov Chain, Examples including 2-state chain, random walk, etc., Transition probability matrix, order of a Markov chain, Markov chain as graphs, Classification of states of a Markov Chain, Stationary distribution,Limiting distribution,period of a Markov Chain, Convergence theorem. **45L**
	Unit 3 Poisson Process: postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, birth and death process, pure death process. **45L**
	Unit 4 Queuing System: General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof). **28L**
List of Practical	Calculation of transition probability matrix. Identification of characteristics of reducible and irreducible chains. Identification of types of classes. Identification of ergodic transition probability matrix Stationarity of Markov chain. Computation of probabilities in case of generalizations of independent Bernoulli trials. Calculation of probabilities for given birth and death rates and vice versa. Calculation of probabilities for Birth and Death Process.

	Calculation of probabilities for Yule Furry Process. Computation of inter-arrival time for a Poisson process. Calculation of Probability and parameters for (M/M/1) model and change in behaviour of queue as N tends to infinity.
Reading/Reference Lists	P. G. Hoel, S. C. Port and C. J. Stone: Introduction to Stochastic Processes. Medhi, J. (2009): Stochastic Processes, New Age International Publishers. S. Karlin and H.M.Taylor: A first course in stochastic process. S. Ross: Stochastic Process. J. G. Kemeny, J. L. Snell and A. W. Knapp: Finite Markov Chains. Bhat,B.R.(2000): Stochastic Models: Analysis and Applications, New Age International Publishers. Taha, H. (1995): Operations Research: An Introduction, Prentice- Hall India. Feller, William (1968): Introduction to probability Theory and Its Applications, Vol I, 3rd Edition, Wiley International. R. N. Bhattacharya and E. Waymire: Stochastic Process and Applications.

Semester	**FIVE/SIX**
Group	**1**
Paper Number	**02**
Paper Title	**Econometrics**
No. of Credits	**6**
No. of classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) various important econometric models and relevant model building concepts. (b) outlier detection, general linear models and estimation of inherent model parameters. (c) multicollinearity, its detection and consequences and related inferential aspects. (d) some advanced concepts of generalised least squares estimation, autocorrelation; its consequences, detection and strategy for reducing autocorrelation. (e) heteroscedasticity and its inherent concepts including its consequences. (f) model selection, step-wise regression, checking for normality.
Syllabus	**Unit 1** What is Econometrics : Comparing mathematical and econometric model with illustrative examples – consumption and production function, Stages of econometric methodology, Review of linear model and assumptions. Dummy variable regression model and qualitative data. **25L**
	Unit 2 Outlier detection: Outlier and influential observations, residuals and leverages, DFBETA, DFFIT and Cook's distance. Heteroscedasticity: Nature of heteroscedasticity – illustrative examples, OLS method under heteroscedasticity and its consequences, detecting heteroscedasticity – residual plot, Glejser test, Goldfeld-Quandt test, remedial measure through variable transformation and generalized least squares (GLS). **35L**

	Unit 3 Autocorrelation: Nature of autocorrelation – illustrative examples, OLS method under autocorrelation – AR(1) model, detecting autocorrelation – residual plot, Runs test, Durbin-Watson test, GLS method for correcting autocorrelation. Multicollinearity: Nature of multicollinearity – illustrative examples, OLS method under perfect multicollinearity and its consequences, detecting multicollinearity – thumb rules based on R^2, pair-wise and partial correlations, remedial measures via more data, dropping and transformation of variables. **35L**
	Unit 4 Model Selection: Adjusted R2, Mallow's Cp criteria, AIC. Best subset selection, Step-wise regression methods. Checking for normality: Q-Q plots, Normal Probability plot, Kolmogorov-Smirnov test and Shapiro-Wilks test. **33L**
List of Practical	*The entire practical are to be done preferably by using R/ statistical packages.* Fitting of ordinary linear regression equations with diagnostics. Tests of heteroscedasticity. Fitting of regression equation after making adjustments for heteroscedasticity. Tests of autocorrelation. Fitting of regression equation after making adjustments for autocorrelation. Tests of multicollinearity. Fitting of regression equation after making adjustments for multicollinearity.
Reading/Reference Lists	G.S. Maddala: Introduction to Econometrics. D.N. Gujarati: Basic Econometrics. J. Johnston and J. Dinardo: Econometric Methods.

Semester	**FIVE/SIX**
Group	**1**
Paper Number	**03**
Paper Title	**Advanced Statistical Methods**
No. of Credits	**6**
No. of classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) smoothing, nearest-neighbour regression, prediction error, in-sample error, splitting of data-set, cross-validation. (b) idea of density estimation and methods, Jackknife and Bootstrap, missing data analysis. (c) Circular data, different characteristics and measures. (d) Circular correlation and regression. (e) Circular probability distributions - Uniform, Cardioid, Circular Normal (CN), Wrapped Normal (WN), Wrapped Cauchy (WC) and associated sampling distributions.
Syllabus	**Unit 1**

	Review of linear regression models, Two goals – Prediction and Inference, Comparison of parametric and Non-parametric regression models in this context. Concept of smoothing, Bias and Variance trade-off, Linear regression as linear smoothers - criticism, Other linear smoothers - Nearest Neighbour Regression, Kernel Regression and Spline with one covariate (only statements of results). Prediction error in regression models, in-sample error and generalization error, splitting of dataset (training set and test set) and idea of cross-validation. Selection of tuning parameters (degree of polynomial for polynomial regression, choice of K in K-NN and bandwidth in kernel regression) through cross-validation. **40L**
	Unit 2 Density estimation: Histogram, Empirical Distribution function and Glivenko-Cantelli Lemma (Statement only), Kernel density estimates- Bias and Variance, Choice of band width. Introduction to Jackknife and Bootstrap, Bias reduction using Jackknife, Estimate of bias of standard statistics, Bootstrap sampling distribution of standard statistics, Bootstrap in regression models. Missing data analysis: MCAR, MAR and NMAR, Brief discussion on Imputation techniques, EM algorithm and properties (statement only), application to mixture models. **48L**
	Unit 3 Circular Data: Applications and Background, Measure of Centre, Circular Distance and Measure of Dispersion, Higher Moments. Circular Correlation and Regression: Circular Correlation Measure, Rank Correlation, Circular-Linear Correlation, Circular-Circular Regression, Linear-Circular Regression. **20L**
	Unit 4 Circular Probability Distributions: Some Methods of Obtaining Circular Distributions, Uniform Distribution, Cardioid Distribution, Circular Normal (CN) Distribution, Wrapped Normal (WN) Distribution, Wrapped Cauchy (WC) Distribution. Sampling Distribution (Statement and Use only) and Estimation of parameters for Circular Normal (CN) Distribution. **20L**
List of Practical	*The entire practical are to be done preferably by using R/ statistical packages.* Case study using linear regression to demonstrate the inferential aspects. Simulation of bias, variance and prediction error in case of linear regression. Plotting the prediction error, bias and variance as function of tuning parameters through simulation (for all linear smoothers). K- fold cross validation to estimate the error in linear smoothers. Fitting of K-NN, Kernel regression and spline models. Kernel density estimates. Jackknife and Bootstrap. Standard applications of EM algorithm. Visualization of circular data. Summary measures of circular data. Regression for circular data.
Reading/Reference Lists	Larry Wasserman: All of Non-parametric Statistics. Gareth James et.al.: Introduction to Statistical Learning (with applications in R). Györfi, László, et. al.: A Distribution-Free Theory of Nonparametric Regression. Simonoff, Jeffrey S. (1996). Smoothing Methods in Statistics. Davison, A. C. and D. V. Hinkley (1997). Bootstrap Methods and their Applications. B.Efron : The Jackknife, the Bootstrap and other Sampling Plans.

	D.Rubin & R.J.A. Little : Statistical Analysis with Missing Data. S. Rao Jammalamadaka, A. Sengupta : Topics in Circular Statistics. Mardia, K and Jupp, P.E. : Directional Statistics. Fisher, N. I.: Statistical Analysis of Circular Data.

Semester	**FIVE/SIX**
Group	**2**
Paper Number	**01**
Paper Title	**Biostatistics**
No. of Credits	**6**
No. of classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) survival functions, Type-I (time), Type-II (order) and random censoring. (b) Failure rate, mean residual life, Total time on Test. (c) applications of exponential, gamma, Weibull distributions, lognormal, Pareto, linearfailure rate distributions to lifetime data. (d) ageing properties of IFR, IFRA, DMRL, NBU, NBUE and HNBUE and Dual classes. (e) Actuarial and Kaplan-Meier estimator of survival function. (f) Cox's proportional hazards and competing risk models, tests for exponentiality. (g) epidemic models, duration of epidemic. (h) idea of clinical trial, types of control groups, ethics of randomisation, different application of randomisation.
Syllabus	**Unit 1** Survival Analysis: Functions of survival times, survival distributions and their applications, exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shaped hazard function. Censoring Schemes: Type I, Type II and progressive or random censoring with biological examples. Estimation of mean survival time and variance of the estimator for Type I and Type II censored data with numerical examples. Non-parametric methods: Actuarial and Kaplan-Meier methods for estimating survival function and variance of the Estimator. **45L**
	Unit 2 Competing Risk Theory: Indices for measurement of probability of death under competing risks and their inter-relations. Estimation of probabilities of death using maximum likelihood principle and modified minimum Chi-square methods. Theory of independent and dependent risks. Bivariate normal dependent risk model. **30L**
	Unit 3 Stochastic Epidemic Models: Simple epidemic models, general epidemic model definition and concept (without derivation). Duration of an epidemic. **20L**
	Unit 4 What is clinical trial? Different phases; Major steps of executing a controlled clinical trial;

	Type of control groups; Blinding; Bias; Ethics of randomization. Determination of trial size; Randomized clinical trial; Balancing treatment assignments; Complete and restricted randomization; Random allocation rule; Truncated binomial design. Concepts of covariate-adaptive and response-adaptive randomization with examples. **33L**
List of Practical	*The entire practical are to be done preferably by using R/ statistical packages.* To estimate survival function. To determine death density function and hazard function. To identify type of censoring and to estimate survival time for type I censored data. To identify type of censoring and to estimate survival time for type II censored data. To identify type of censoring and to estimate survival time for progressively type I censored data. Estimation of mean survival time and variance of the estimator for type I censored data. Estimation of mean survival time and variance of the estimator for type II censored data. Estimation of mean survival time and variance of the estimator for progressively type I censored data. To estimate the survival function and variance of the estimator using Non-parametric methods with Actuarial methods. To estimate the survival function and variance of the estimator using Non-parametric methods with Kaplan-Meier method. To estimate Crude probability of death. To estimate Net-type I probability of death. To estimate Net-type II probability of death. To estimate partially crude probability of death. To simulate the random sequence of treatment assignments. To plot the probability of imbalance. To simulate the treatment allocation ratio.
Reading/Reference Lists	Lee, E.T. and Wang, J.W. (2003): Statistical Methods for Survival data Analysis, 3rd Edition, John Wiley and Sons. Biswas, S. (2007): Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, Reprinted 2ndCentral Edition, New Central Book Agency. Chiang, C.L. (1968): Introduction to Stochastic Processes in Bio Statistics, John Wiley and Sons. Indrayan, A. (2008): Medical Biostatistics, 2nd Edition Chapman and Hall/CRC. Rosenberger and Lachin: Randomized Clinical Trials: Theory and Practice. Ding-Geng (Din) Chen and Karl E. Peace: Clinical Trial Data Analysis Using R

Semester	**FIVE/SIX**
Group	**2**
Paper Number	**02**
Paper Title	**Advanced Mathematical Analysis**
No. of Credits	**6**
No. of classes	Theory : 5 Practical : 1
Course Learning Outcomes	Students will acquire knowledge of (a) Partial order, relations, partitions, metric space, topology, different sets.

	(b) Bolzano-Weierstrass theorem, compactness. (c) Group theory and its properties, ring, field. (d) Hilbert spaces, applications in statistics, Introduction to fourier series. (e) Analytic function, contour integration, Fourier and Laplace transforms.
Syllabus	**Unit 1** Intuitive set theory; partial order; equivalence relations and partitions; Countable and uncountable sets; Zorn's lemma and the well ordering principle (Statement only) Elements of metric space theory: sequences and Cauchy sequences and the notion of completeness, construction of real numbers, elementary topological notions for metric spaces: open sets, closed sets, compact sets, connectedness, continuous and uniformly continuous functions on a metric space. The Bolzano - Weierstrass theorem, supremum and infimum on compact sets. Separability, Completeness. **35L**
	Unit 2 Introduction to Group Theory: Definition, Elementary properties using definition, integral powers of elements, Subgroups, Cyclic group, Groups of Permutations. Definition of Ring, Special types of Rings: Integral Domain, Field, elementary results. **15L**
	Unit 3 Review of Axiomatic approach of vector spaces, Inner product spaces, Orthogonal complement and Projections. Expectation as inner product and application in statistics. Hilbert spaces, Applications in statistics, Introduction to fourier series. **15L**
	Unit 4 Analytic function, Cauchy-Riemann equations. Statement of Cauchy theorem and of Cauchy integral formula with applications, Taylor's series. Singularities, Laurent series. Residue and contour integration. Fourier and Laplace transforms. Application in characteristic functions. **31L**
List of Practical	Only Tutorials.
Reading/Reference Lists	W. Rudin : Principles of Mathematical Analysis. G.F. Simmons: Introduction to Topology and Modern Analysis. S. Kumaresan : Topology of Metric Spaces. S. Shirali and H.L.Vasudeva : Metric Spaces. A. Chakraborty : Metric Space. J. C. Burkill and H. Burkill: A second course in Mathematical Analysis. J.B. Conway : Functions of one complex variable. I.N. Herstein : Topics in Algebra. Sen, Ghosh, Mukhopadhay : Topics in Abstract Algebra. M. Artin : Algebra.

Semester	**FIVE/SIX**
Group	**2**
Paper Number	**03**
Paper Title	**Operations Research**

No. of Credits	**6**
No. of classes	Theory : 4 Practical : 4
Course Learning Outcomes	Students will acquire knowledge of (a) tackling various types of OR problems and mathematical formulation of linear programming problem (LPP). (b) graphical and simplex method of solving LPP for finding degenerate, unbounded, alternate and infeasible solutions. (c) concept of duality in LPP, simplex duality. (d) Transportation Problem: Initial solution and the optimal solution, special cases. (e) assignment problem: Hungarian method to find optimal assignment, special cases of assignment problem. (f) Hungarian Method for solving assignment problems. (g) game theory for graphical solution of m 2 or 2 n rectangular game and mixed strategy and solutions. (h) non-linear programming with different types of problems and solution methods.
Syllabus	**Unit 1** Introduction to Operations Research, phases of O.R., model building, various types of O.R. problems. Linear Programming Problem, Mathematical formulation of the L.P.P, graphical solutions of a L.P.P. Simplex method for solving L.P.P. Charne's M-technique for solving L.P.P. involving artificial variables. Special cases of L.P.P. Concept of Duality in L.P.P: Dual simplex method. **40L**
	Unit 2 Transportation Problem: Initial solution by North West corner rule, Least cost method and Vogel's approximation method (VAM), MODI's method to find the optimal solution, special cases of transportation problem. Assignment problem: Hungarian method to find optimal assignment, special cases of assignment problem. **20L**
	Unit 3 Game theory: Rectangular game, minimax-maximin principle, solution to rectangular game using graphical method, dominance and modified dominance property to reduce the game matrix and solution to rectangular game with mixed strategy. **20L**
	Unit 4 Introduction to nonlinear programming. Unconstrained problems,problems with inequality and equality constraints,Fritz John and Karush-Kuhn-Tucker conditions. **16L**
List of Practical(Using TORA/WINQSB/LINGO)	Mathematical formulation of L.P.P and solving the problem using graphical method, Simplex technique and Charne's Big M method involving artificial variables. Identifying Special cases by Graphical and Simplex method and interpretation Degenerate solution Unbounded solution Alternate solution Infeasible solution Allocation problem using Transportation model. Allocation problem using Assignment model. Problems based on game matrix. Graphical solution to mx2 / 2xn rectangular game. Mixed strategy. Applications of KKT conditions.

Reading/Reference Lists	Taha, H. A. (2007): Operations Research: An Introduction, 8 Hall of India. KantiSwarup, Gupta, P.K. and Manmohan (2007): Operations Research, 13th Edition, Sultan Chand and Sons. Hadley, G: (2002) : Linear Programming, Narosa Publications. Hillier, F.A and Lieberman, G.J. (2010): Introduction to Operations Research- Concepts and cases, 9th Edition, Tata McGraw Hill. Bazaraa M.S. et.al., Linear programming and Network flows. Bazaraa M.S. et.al., Non-linear programming: Theory and Algorithms.

Semester	**FIVE/SIX**
Group	**2**
Paper Number	**04**
Paper Title	**Project Work**
No. of Credits	**6**
No. of classes	8
Course Learning Outcomes	Students will acquire knowledge of (a) analysing and interpreting and taking appropriate decisions in solving real life problems using statistical tools. (b) use different Statistical packages for graphical interface, data analysis and interpretation. (c) write a systematic Statistical project report.
Syllabus	The aim of the course is to initiate students to write and present a statistical report, under the supervision of a faculty, on some areas of human interest. The project work will provide hands on training to the students to deal with data emanating from some real life situations and propel them to dwell on some theory or relate it to some theoretical concepts.

Generic Elective Papers

Semester	**ONE**
Paper Number	**STAT01GE01**
Paper Title	**Introductory Statistics and Probability**
No. of Credits	**6**
No. of classes	Theory : 4 Practical : 4
Course Learning Outcomes	This course will make the students conversant with (a) various techniques used in summarization, presentation and analysis of different types of Statistical data. (b) various summary measures of central tendency, dispersion, moments, skewness and

	kurtosis. (c) simple and rank correlation, Partial and Multiple correlation coefficients. (d) fitting of linear and quadratic regressions using principle of least squares. (e) measures of association for 2×2 and $r\times s$ contingency tables. (f) have knowledge on theoretical as well as practical approach. (g) probability theory and Statistical modelling of outcomes of real life random experiments through various Statistical distributions. (h) writing of sample space, events and algebra of events and finding Probability of events. (i) conditional Probability and applications of Theorem of total probability and Bayes' theorem. (j) discrete and continuous Random Variables, Probability mass function (p.m.f.) and Probability density function (p.d.f.), Cumulative distribution function (c.d.f.). (k) Expectation, variance, moments and moment generating function. (l) problem solving pertaining to binomial, Poisson, geometric, uniform, normal and exponential distributions. (m) fitting of Binomial, Poisson and Normal distributions. (n) various aspects as outlined above through practical assignments.
Syllabus	**Unit 1** Introduction to statistics: Definition and scope, concepts of population and sample, Data: Types of data, scales of measurement, Presentation of data. Descriptive measures of data. **40L**
	Unit 2 Introduction to bivariate data: scatter diagram, idea of correlation and regression, rank correlation. Theory of attributes: consistency of data, independence and association of two attributes, different measures of association and two-way contingency table. **20L**
	Unit 3 Introduction to probability: random experiments, sample space, events. Definitions of Probability – classical, statistical. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and applications. **40L**
	Unit 4 Random Variables: Discrete and continuous random variables, p.m.f., p.d.f. ,c.d.f. Concepts of expectation, variance, other moments and moment generating function. Standard probability distributions: Binomial, Poisson, geometric, uniform, normal, exponential etc. **28L**
List of Practical	Presentation of data. Problems based on descriptive measures. Fitting of polynomials, exponential curves. Karl Pearson correlation coefficient. Spearman rank correlation with and without ties. Correlation coefficient for a bivariate frequency distribution. Lines of regression, angle between lines and estimated values of variables. Checking consistency of data and finding association among attributes. Fitting of binomial distributions. Fitting of Poisson distributions.

	Application problems based on binomial distribution. Application problems based on Poisson distribution. Problems based on area property of normal distribution. Application based problems using normal distribution. Fitting of normal distribution.
Reading/Reference Lists	Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I& II, 8th Edn. The World Press, Kolkata. Das, N.G.: Statistical Methods, Vol I and II, Tata McGraw Hill Pub. Co. Ltd. Goon, A.M., Gupta M.K. and Dasgupta B. (2002): An Outline of Statistical Theory, Vol. I , The World Press, Kolkata. Freedman, D.A. et.al. Statistics, Viva Norton Student Edition. Ross, S.M, A first course in Probability, Pearson.

Semester	**TWO**
Paper Number	**STAT02GE02**
Paper Title	**Sampling and Inference**
No. of Credits	**6**
No. of classes	Theory: 4 Practical: 4
Course Learning Outcomes	This course will make the students conversant with (a) ideas of parameter, random samples, statistic, and sampling distribution of a statistic. (b) some useful sampling distributions based on samples from normal population. (c) bivariate normal distribution and applications of sampling from bivariate normal. (d) polytomous data and the concept of the multinomial probability model. (e) statistical inference, point estimation, interval estimation, and hypothesis testing, concept and application of *p*-value. (f) sampling frame and design, SRSWR and SRSWOR, determination of sample size, stratified sampling, cluster sampling, systematic sampling.
Syllabus	**Unit 1** Sampling distribution: parameter, random samples, statistic, sampling distribution of a statistic, outline (without detailed proof) of the definitions and properties of some useful sampling distributions based on samples from normal population. **34L**
	Unit 2 Introduction to bivariate normal distribution and its important properties (derivation not required), sampling from bivariate normal (applications only), polytomous data and the concept of the multinomial probability model (statement only) as supporting probability distribution to sampling related to polytomous data. **26L**

	Unit 3 Introductory statistical inference: Meaning of statistical inference, basic discussions with examples on point estimation, interval estimation, and hypothesis testing, concept and application of *p*-value. **28L**
	Unit 4 Introductory survey sampling from finite population: Ideas of Sampling frame and design, Concept of SRSWR and SRSWOR, sample size determination, Notions of Stratified and Cluster sampling, Systematic sampling. **40L**
List of Practical	Checking normality of bivariate data through plots. To select an SRS with and without replacement from finite populations, theoretical populations and given geometrical shapes. For a population of size 5, estimate population mean, population mean square and population variance. Enumerate all possible samples of size 2 by WR and WOR and establish all properties relative to SRS. For SRSWOR, estimate mean, standard error and the sample size. Finding size and power of a critical region.
Reading/Reference Lists	Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I& II, 8th Edn. The World Press, Kolkata. Das, N.G.: Statistical Methods, Vol I and II, Tata McGraw Hill Pub. Co. Ltd. Freedman, D.A. et.al. Statistics, Viva Norton Student Edition. Mood, A.M. Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn., (Reprint), Tata McGraw-Hill Pub. Co. Ltd. Cochran, W.G. (1984): Sampling Techniques (3rd Ed.), Wiley Eastern.

Semester	**THREE**
Paper Number	**STAT03GE03**
Paper Title	**Applied Statistical Inference**
No. of Credits	**6**
No. of classes	Theory: 4 Practical: 4
Course Learning Outcomes	This course will make the students conversant with (a) estimation of parameters using moments and maximum likelihood. (b) exact tests and confidence intervals related to univariate and bivariate normal populations, types critical regions of a given test-statistic. (c) ideas of large sample distributions and large sample tests related to sample proportion, sample mean, sample correlation etc. and applications. (d) nonparametric methods of inference including (i) ordinary sign test and Wilcoxon signed-rank test for single-sample and paired sample data, (ii) Mann-Whitney test for two-sample problem, (iii) Kolmogorov-Smironov Approach.

	(e) Pearsonian chi-square tests and applications. (f) an outline of the methods of ANOVA under one-way and two-way classified data. (g) necessity for test for normality and Levin's test for homoscedasticity. (h) Kruskal-Wallis test.
Syllabus	**Unit 1** Methods of small sample inference: Method of moments, Method of maximum likelihood, heuristic approach of deciding nature of the critical region (right, or left or two-tailed) based on a given test statistic, illustrations of exact tests and confidence intervals related to univariate and bivariate normal populations. **34L**
	Unit 2 Large sample inference: Outline of the large sample distributions and large sample tests related to sample proportion, sample mean, sample correlation etc. along with applications. **20L**
	Nonparametric inference: Necessity and usefulness of nonparametric methods of inference, illustration of the outlines of (i) ordinary sign test and Wilcoxon signed-rank test for single-sample and paired sample data, (ii) Mann-Whitney test for two-sample problem, (iii) Kolmogorov-Smironov Approach, through examples, Pearsonian chi-square tests (statement only) and applications. **40L**
	Unit 4 Analysis of Variance (ANOVA): Outline of the methods of ANOVA under one-way and two-way classified data, necessity for test for normality and Levin's test for homoscedasticity, Kruskal-Wallis test, interpretations of decisions taken in ANOVA. **34L**
List of Practical	Estimators of population mean. Confidence interval for the parameters of a normal distribution (one sample and two sample problems). Tests of hypotheses for the parameters of a normal distribution (one sample and two sample problems). Chi-square test of proportions. Chi-square tests of association. Chi-square test of goodness-of-fit. Test for correlation coefficient. Sign test for median. Sign test for symmetry. Wilcoxon and Mann-Whitney two-sample test. Analysis of Variance of a one-way classified data. Analysis of Variance of a two-way classified data. Kolmogorov-Smirnov tests.
Reading/Reference Lists	Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I& II, 8th Edn. The World Press, Kolkata. Das, N.G.: Statistical Methods, Vol I and II, Tata McGraw Hill Pub. Co. Ltd. Freedman, D.A. et.al. Statistics, Viva Norton Student Edition. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals Of Mathematical Statistics, Sultan Chand & Sons. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals Of Applied Statistics, Sultan Chand &

	Sons. Gibbons J.D. and Chakraborty, S., Nonparametric Statistical Inference, CRC Press. Mukhopadhaya, P., Mathematical Statistics.

Semester	**FOUR**
Paper Number	**STAT04GE04**
Paper Title	**Applied Multivariate and Regression Models**
No. of Credits	**6**
No. of classes	Theory : 4 Practical : 4
Course Learning Outcomes	This course will make the students conversant with (a) multivariate data: mean vector, dispersion matrix, correlation matrix. (b) multiple linear regressions, multiple correlation (R) and partial correlation, including use of R^2 and adjusted-R^2. (c) ideas and applications of principal component analysis, factor analysis, cluster analysis and discriminant analysis. (d) general linear model, use of dummy variables, concept of interaction, models including quantitative and qualitative covariates. (e) estimation using Least Square Technique, Gauss-Markov Theorem. (f) general linear Hypothesis and applications in different models, confidence interval and prediction interval. (g) Outliers, influential observations, idea of heteroscedasticity and autocorrelation, multicollinearity. Model selection techniques like AIC, Mallow Cp (h) Concept of training set and test set, Cross-validation, Forward and Backward selection. (i) idea of regression for binary and count data.
Syllabus	**Unit 1** Introduction to multivariate data: mean vector, dispersion matrix, correlation matrix. Multiple linear regressions, multiple correlation (R) and partial correlation, Use of R^2 and Adjusted R^2. **32L**
	Unit 2 Principal component analysis and Factor analysis, Cluster analysis and Discriminant analysis (data oriented approach). **32L**
	Unit 3 Concept of General linear model, use of dummy variables, concept of interaction, models including quantitative and qualitative covariates (examples only). Estimation under General Linear Model: Least Square Technique, Gauss-Markov Theorem (Statement Only), General linear Hypothesis (Statement only) and applications in different models, confidence interval and prediction interval. **32L**

	Unit 4 Outliers and influential observations, Idea of problem of heteroscedasticity and autocorrelation, Multicollinearity, Model selection techniques: AIC, Mallow Cp (Derivations Excluded). Concept of training set and test set, Cross-validation. Forward and Backward selection. Idea of regression for binary and count data. **32L**
List of Practical	Computation of sample mean vector and variance-covariance matrix. Fitting of multiple linear regression and interpretation. Calculation of multiple correlation and partial correlation coefficient. Principal component analysis using software packages. Factor Analysis using software packages. Cluster Analysis using software packages. Linear Discriminant Analysis using software packages. Fitting of dummy variable regression models. Testing of hypothesis, confidence interval and prediction interval related to linear regression models. Regression Diagnostics using residual plots. Model selection using software packages. Logistic regression using software packages. Regression for count data using software packages.
Reading/Reference Lists	Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. I, 9th Edition World Press, Kolkata. Das, N.G.: Statistical Methods, Vol I, Tata McGraw Hill Pub. Co. Ltd. Johnson, R.A. and Wichern, D.W. Applied Multivariate Statistical Analysis, PHI. Hardle W. and Simar, L. Applied Multivariate Statistical Analysis. Kutner, M.H. et.al., Applied Linear Statistical Models. Belsley D.A. et.al., Regression Diagnostics. Draper N.R. and Smith, H. Applied Regression Analysis.