Presidency University, Kolkata

SYLLABUS

IN

B.Sc. STATISTICS (Honours) 2018

Under

Choice Based Credit System

Semesters 1 – 6

(With effect from Academic Session 2018 – 2019)

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

Department of Statistics
Presidency University

CONTENT

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

Skill Enhancement Electives (SEE) [Credit : 4 each, 2 papers 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

Discipline Specific Elective Papers (DSE) [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. Survival Analysis and 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 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 paper(s) that may be offered depending upon the availability of faculty and resources.

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

1. Statistical Methods
2. Introductory Probability
3. Basics of Statistical Inference
4. Applied Statistics

Scheme for Choice Based Credit System in B.Sc. (Honours) Statistics

1.1 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

1.2 Scheme for CBCS Curriculum

Semester	Course Name	Paper Code	Course Detail	Credits	Marks
I	Ability Enhancement Compulsory Course–I	STAT01AECC01	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** from other Subjects	4/5	70/80
	Generic Elective–1Practical/ Tutorial		Practical/Tutorial	2/1	30/20

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Semester	Course Name	Paper Code	Course Detail	Credits	Marks
II	Ability Enhancement Compulsory Course–II	STAT02AECC02	English Communication /MIL	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
	SkillEnhancementCourse-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

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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 Group-1 of **Discipline Specific Electives (DSE)**	4	70
	Discipline Specific Elective–1 Practical/ Tutorial		Practical/ Tutorial	2	30
	Discipline Specific Elective–2	STAT05DSE02	Any one from Group-2 of **Discipline Specific Electives (DSE)**	4/5	70/80
	Discipline Specific Elective– 2 Practical/ Tutorial		Practical/ Tutorial	2/1	30/20
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 Group-1 of **Discipline Specific Electives (DSE)**	4	70
	Discipline Specific Elective–3 Practical/ Tutorial		Practical/ Tutorial	2	30
	Discipline Specific Elective–4	STAT06DSE04	Any one from Group-2 of **Discipline Specific Electives (DSE)**	4/5	70/80
	Discipline Specific Elective–4 Practical/ Tutorial		Practical/ Tutorial	2/1	30/20
				Total	2600

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

N.B:-

1. The lecture hours calculation in all the papers includes 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.

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
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 Practical	1. Graphical representation of data. 2. Problems based on measures of central tendency. 3. Problems based on measures of dispersion. 4. Problems based on combined mean and variance and coefficient of variation. 5. Problems based on moments, skewness and kurtosis. 6. Fitting of polynomials, exponential curves. 7. Karl Pearson correlation coefficient. 8. Correlation coefficient for a bivariate frequency distribution. 9. Lines of regression, angle between lines and estimated values of variables. 10. Correlation ratio and correlation index. 11. Rank correlation with and without ties.

	12. Computation of intra class correlation coefficient 13. Problems on measures of association.
Reading/Reference Lists	1. Freedman, Pisani, Purves: Statistics 2. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edn. The World Press, Kolkata. 3. Yule G.U. and Kendall M.G. : An Introduction to the Theory of Statistics.. 4. Snedecor & Cochran : Statistical Methods (6th ed) 5. Croxton F.E., Cowden D.J. & Klein : Applied General Statistics 6. Moore, D.S & Notz. W.I.: Statistics – Concepts and Controversies. 7. Siegel, A.F. & Morgan, C.J.: Statistics and Data Analysis – An Introduction. 8. Wallis F.E. & Roberts H.V. : Statistics- a new approach 9. Lewis-Beck M.S. (ed.) : Regression Analysis 10. 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
	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 Practical	Tutorial Only
Reading/Reference Lists	1. S.M. Ross : A First Course in Probability. 2. Feller W.: An Introduction to Probability Theory & its Applications

	3. Anirban DasGupta: Fundamentals of Probability- A First Course 4. K.L. Chung : Elementary Probability Theory with Stochastic Process. 5. Rohatgi V.K. (1984): An Intro. to Probability Theory & Math. Statistics 6. Chandra T.K. & Chatterjee D. : A First Course in Probability 7. Goon A.M., Gupta M.K. & Dasgupta B.: An Outline of Statistical Theory (Vol-1) 8. Hoel P.J., Port S.C. & Stone C.J.: Introduction to Probability Theory (Vol-1) 9. Cramer H. : The Elements of Probability Theory 10. Parzen E. : Modern Probability Theory and its Applications 11. Uspensky J.V. : Introduction to Mathematical Probability 12. Cacoullos T. : Exercises in Probability 13. Pitman J. : Probability 14. Stirzaker D. : Elementary Probability 15. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi. 16. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia. 17. 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
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	1. Linear independence and dependence. 2. Orthogonality and Gram-Schmidt Orthogonalization Process. 3. Basis and Dimension. 4. Basis of sum, intersection and complement of subspaces. 5. Projection of vectors on a subspace. 6. Determinant of a matrix 7. Inverse of matrix. 8. Rank and Rank factorization of matrices. 9. Elementary transformations 10. Solutions of system of linear equations. 11. Finding g-inverse of a matrix 12. Problems on quadratic forms. 13. Problems relayed to characteristic roots and vectors. 14. Power method of finding characteristic roots. 15. Problems related to linear transformations.
Reading Reference List	1. Hadley G. : Linear Algebra 2. Rao A.R. & Bhimasankaram P. : Linear Algebra 3. Searle S.R. : Matrix Algebra – useful for Statistics 4. Rao C.R. : Linear Statistical Inference & its Applications 5. Hoffman K. & Kunze R. : Linear Algebra 6. 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
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 Practical	1. Fitting of binomial distribution for given n and p. 2. Fitting of binomial distribution after computing mean and variance 3. Fitting of Poisson distribution for given value of lambda 4. Fitting of Poisson distribution after computing mean. 5. Fitting of negative binomial. 6. Fitting of suitable distribution. 7. Application problem based on binomial distribution 8. Application problem based on Poisson distribution. 9. Application problem based on negative binomial distribution. 10. Problems based on are property of normal distribution. 11. To find the ordinate for a given area for normal distribution. 12. Application based problems using normal distribution. 13. Fitting of normal distribution when parameters are given . 14. Fitting of normal distribution when parameters are not given. 15. Fitting of some other continuous distributions. 16. Scaling of scores. 17. Fitting of truncated distributions.
Reading/Reference Lists	1. S.M. Ross : A First Course in Probability. 2. Feller W.: An Introduction to Probability Theory & its Applications 3. Anirban DasGupta: Fundamentals of Probability- A First Course 4. K.L. Chung : Elementary Probability Theory with Stochastic Process. 5. Rohatgi V.K. (1984): An Intro. to Probability Theory & Math. Statistics 6. Chandra T.K. & Chatterjee D. : A First Course in Probability 7. Goon A.M., Gupta M.K. & Dasgupta B.: An Outline of Statistical Theory (Vol-1) 8. Hoel P.J., Port S.C.&Stone C.J.: Introduction to Probability Theory (Vol-1) 9. Cramer H. : The Elements of Probability Theory 10. Parzen E. : Modern Probability Theory and its Applications 11. Uspensky J.V. : Introduction to Mathematical Probability 12. Cacoullos T. : Exercises in Probability 13. Pitman J. : Probability 14. Stirzaker D. : Elementary Probability 15. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.

	16. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia. 17. 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
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 $r^n, (1+\frac{1}{n})^n$ 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 Practical	Tutorials only

Reading/Reference Lists	1. R G Bartle, Sherbert D R.: Introduction to Real Analysis 2. Apostol, T.M. : Mathematical Analysis 3. Malik, S.C.& Arora, S. : Mathematical Analysis 4. Kumaresan, S:A Basic Course in Real Analysis 5. 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
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. Binomial proportion(s), Poisson mean(s), Univariate Normal mean (s), standard deviation(s). Standard tests related to Bivariate normal parameters. **38L**
List of Practical	1. Testing of significance for single proportion and difference of two proportions. 2. Testing of significance for single Poisson mean and difference of means of two independent Poisson distributions. 3. Testing of significance and confidence intervals for single mean and difference

	of two means and paired tests. 4. Testing if the population variance has a specific value and its confidence intervals 5. Testing of significance and confidence intervals of correlation coefficient. 6. Testing of equality of population variances for two independent normal populations and related confidence intervals. 7. Testing of ratio of variances for bivariate normal population and related confidence interval. 8. Tests related to regression and related confidence intervals.
Reading/ Reference List	1. Rohatgi V.K. (1984): An Intro. to Probability Theory & Math. Statistics 2. Mukhopadhay, N.: Probability and Statistical Inference 3. Goon A.M., Gupta M.K. & Dasgupta B.: An Outline of Statistical Theory (Vol-1) 4. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edn. The World Press, Kolkata. 5. 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. 6. Casella , G. and Berger R.L. (2002).: Statistical Inference, 2ndEdn. Thomson Learning 7. 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
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 Practical	1. Roots of a quadratic equation (with imaginary roots also). 2. Sorting of an array and hence finding median. 3. Mean, Median and Mode of a Grouped Frequency Data. 4. Variance and coefficient of variation of a Grouped Frequency Data. 5. Preparing a frequency table. 6. Value of n factorial using recursion. 7. Random number generation from uniform, exponential, calculate sample mean and variance and compare with population parameters. 8. Matrix addition, subtraction, multiplication, Transpose and Trace. 9. Fitting of Binomial, Poisson distribution. 10. Compute ranks and then calculate rank correlation (without tied ranks). 11. Fitting of lines of regression. 12. Numerical methods: Solving one-variable equations using Newton-Raphson method. 13. Trapezoidal rule for numerical integration. 14. Solving a linear system of equation. 15. Generation of random samples from standard discrete and continuous distributions

	16. Generation of random samples from mixture distributions 17. Generation of random samples from bivariate normal distribution. 18. General of random samples by acceptance rejection method. 19. Monte Carlo integration and related techniques.
Reading/Reference Lists	1. Kernighan, B.W. and Ritchie, D.(1988): CProgramming Language,2ndEdition, Prentice Hall. 2. Balagurusamy, E. (2011): Programming in ANSI C, 6th Edition Tata McGraw Hill. 3. Ross, S: Simulation 4. Scarborough, J.B. (1966): Numerical Mathematical Analysis. Oxford and IBH Publishing. 5. Mollah, S. A. : Numerical Analysis & Computational Procedures 6. Atkinson K. : Elementary Numerical Analysis 7. Sastry S.S.: Introductory Methods of Numerical Analysis 8. 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
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 ($N=n\times k$). 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 Practical	1. To select an SRS with and without replacement from finite populations, theoretical populations and given geometrical shapes. 2. 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. 3. For SRSWOR, estimate mean, standard error and the sample size 4. Stratified Sampling: allocation of sample to strata by Proportional and Neyman's methods. Compare the efficiencies of above two methods relative to SRS. 5. Estimation of gain in precision in stratified sampling. 6. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend. 7. 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. 8. Cluster sampling: estimation of mean or total, variance of the estimate, estimate of intra-class correlation coefficient, efficiency as compared to SRS. 9. Two stage sampling.
Reading/Reference Lists	1. Cochran, W.G. (1984): Sampling Techniques (3rd Ed.), Wiley Eastern. 2. 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. 3. Murthy, M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta. 4. Des Raj and Chandhok P. (1998): Sample Survey Theory, Narosa Publishing House. 5. Goon A.M., Gupta M.K. and Dasgupta B. (2008): Fundamentals of Statistics, Vol-II, World Press. 6. 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
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- Construction and Statistical basis 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 Practical	1. To calculate CDR and ASDR for a given set of data 2. To find STDR by direct and indirect methods 3. To construct a complete life table. 4. To fill in the missing entries of a life table. 5. 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. 6. To calculate CBR, GFR, SFR, TFR for a given set of data. 7. To calculate crude rate of Natural Increase and Pearle's Vital index for a given set of data.

	8. Calculate GRR and NRR for a given set of data and compare them. 9. Population Estimation and Projection 10. Fitting of logistic equation by Rhode`s method 11. Construction and Interpretation of statistical control charts 12. X-bar & R chart, X-bar & s-chart, np- chart, p-chart, c-chart, u- chart 13. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves. 14. Calculation of process capability and comparison of 3-sigma control limits with specification limits.
Reading/ Reference List	1. Montgomery, D.C. (2009): Introduction to Statistical Quality control, 6th edition, Wiley India, Pvt Ltd 2. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol 2, 8th edition, The world Press, Kolkata 3. Mukhopadhyay, P. (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied(P) Ltd. 4. Montgomery, D.C. and Runger, G.C. (2008): Applied Statistics and Probability for Engineers, 3rd edition reprint, Wiley India Pvt Ltd. 5. Ehrlich, B. Harris (2002): Transactional Six sigma and Lean Servicing, 2nd edition, St Lucie Press 6. Hoyle, David (1995): ISO Quality systems Handbook, 2nd edition, Butterworth Heinemann Publication. 7. Nagar A.L, Das R.K (1997): Basic statistics, Oxford University Press. 8. 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
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 Practical	1. Maximum Likelihood Estimation 2. Estimation by the method of moments, minimum Chi-square 3. Most powerful critical region (NP Lemma) 4. Uniformly most powerful critical region 5. Unbiased critical region 6. Power curves 7. Likelihood ratio tests for simple null hypothesis against simple alternative hypothesis 8. Likelihood ratio tests for simple null hypothesis against composite alternative hypothesis 9. Asymptotic properties of LR tests 10. Testing of significance and confidence intervals for single proportion and difference of two proportions using CLT. 11. Testing of significance and confidence intervals for single Poisson mean and difference of two Poisson means using CLT. 12. Testing of significance and confidence intervals concerning sample standard deviation, coefficient of variation and correlation coefficient (both single sample and two sample cases). 13. Testing of significance and confidence intervals using variance stabilizing transformations. 14. Determination of the minimum sample size required to achieve normality by sample proportion, mean and standard deviation. 15. Tests for goodness of fit, independence and homogeneity using Pearsonian chi-square statistic.
Reading/Reference Lists	1. Rohatgi V.K. (1984): An Intro. to Probability Theory & Math. Statistics 2. Mukhopadhay, N.: Probability and Statistical Inference 3. Goon A.M., Gupta M.K. & Dasgupta B.: An Outline of Statistical Theory (Vol-2) 4. Casella , G. and Berger R.L. (2002).: Statistical Inference, 2ndEdn. Thomson Learning 5. Kale, B.K.: A first course in parametric inference, Narosa. 6. 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
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 for one sample, 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 Practical	*Some practical problems are to be done preferably by using R/ statistical packages.* 1. Multiple Correlation and Regression 2. Partial Correlation 3. Discriminant Analysis using R/statistical packages. 4. Principal Component Analysis using R/statistical packages. 5. Factor Analysis using R/statistical packages. 6. Test for randomness based on total number of runs. 7. Kolmogorov Smirnov test for one sample 8. Sign test 9. Signed Rank test 10. Wilcoxon-Mann Whitney U-test 11. Kruskal-Wallis test 12. Non-parametric confidence intervals. 13. Non-parametric tests using R/statistical packages.
Reading/Reference Lists	1. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rdEdn., John Wiley 2. Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley. 3. Kshirsagar, A.M. (1972): Multivariate Analysis, 1stEdn. Marcel Dekker. 4. Johnson, R.A. And Wichern, D.W. (2007): Applied Multivariate Analysis, 6thEdn., Pearson & Prentice Hall 5. Mukhopadhyay, P.: Mathematical Statistics.

	6. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002): Fundamentals of Statistics, Vol. 1, 8th Edn. The World Press, Kolkata. 7. Gibbons, J. D. and Chakraborty, S (2003): Nonparametric Statistical Inference. 4th Edition. Marcel Dekker, CRC. 8. 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
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 effect 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 Practical	*Some practical problems are to be done preferably by using R/ statistical packages.* 1. Estimability when X is a full rank matrix and not a full rank matrix. 2. Simple linear regression. 3. Multiple regression. 4. Tests for linear hypothesis. 5. Analysis of variance of one-way classified data. 6. Analysis of variance of a two-way classified data with one observation per cell. 7. Analysis of variance of a two-way classified data with equal number of observations per cell. 8. Analysis of covariance of a one-way classified data with one concomitant variable.

	9. Analysis of covariance of a two-way classified data with one concomitant variable. 10. Hypothesis testing in case of simple and multiple regression models and related tests. 11. Fitting of linear model using R/ statistical package 12. Regression diagnostics and checking model assumptions using R/statistical package. 13. Fitting of logistic regression model using R / statistical package
Reading/Reference Lists	1. Goon, A.M., Gupta, M.K., and Dasgupta, B. (2002), Fundamental of Statistics, Volume 1& 2, 8th Edn. The World Press, Kolkata. 2. Scheffe, H, Linear Models 3. Rao, C.R., Linear Statistical Inference. 4. Stapleton, J. H.: Linear Statistical Models 5. Mukhopadhyay, P. (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied(P) Ltd. 6. Sengupta D. and Jammalamadaka, S. R.: Linear Models, An Integrated Approach. 7. Hocking, R. R.: Methods and Applications of Linear Models. 8. Weisburg, S (2005) Applied Linear Regression (Third edition), Wiley. 9. Wu, C. F. J. and Hamada, M. (2009). Experiments, Analysis and Parameter Design Optimization (Second edition), John Wiley. 10. 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
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, Intra-block 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 $2^n (\ n \leq 5\ ), 3^2, 3^3$ factorial experiments. **35L** **Unit 4** Construction of one-half and one-quarter fractions of 2^n ($n \leq 5$) factorial experiments, Alias structure, Resolution of a design. **23L**
List of Practical	1. Analysis of CRD

	2. Analysis of an RBD 3. Analysis of an LSD 4. Analysis of an RBD with one missing observation 5. Analysis of an LSD with one missing observation 6. Intra Block analysis of a BIBD 7. Analysis of 2^2 and 2^3 factorial in CRD and RBD 8. Analysis of 2^2 and 2^3 factorial in LSD 9. Analysis of a completely confounded two level factorial design in 2 blocks 10. Analysis of a completely confounded two level factorial design in 4 blocks 11. Analysis of a partially confounded two level factorial design 12. Analysis of a single replicate of a 2^n design 13. Analysis of a fraction of 2^n factorial design
Reading/Reference Lists	1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8thEdn. World Press, Kolkata. 2. Mukhopadhyay, P. : Applied Statistics. 3. Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House. 4. Dey, A. (1986) : Theory of Block Designs, Wiley Eastern Limited. 5. Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley. 6. Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley EasternLtd. 7. 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
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. **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 Practical	*Some practical problems are to be done preferably by using R/ statistical packages.* 1. Plotting a real life time series, and detecting various features (trend, periodic behaviours etc.). Suggested data sets: a. Sun spot data b. Dollar-Rupee exchange rates c. Stock market data 2. Fitting and plotting of mathematical curves: a. modified exponential curve b. Gompertz curve 3. Fitting of trend by Moving Average Method. 4. Plotting detrended series. 5. Measurement of Seasonal indices Ratio-to-Moving Average method. 6. Plotting ACF and PACF of a given time series. 7. Using Yule-Walker equation to fit AR (1) and AR (2) models to real life data. 8. Forecasting by short term forecasting methods. 9. Forecasting by exponential smoothing. 10. Calculate price and quantity index numbers using simple and weighted average of price relatives. 11. To calculate the Chain Base index numbers. 12. Problems on cost of living index numbers.
Reading/Reference Lists	1. Gun, Gupta and Dasgupta (2002) Fundamentals of Statistics Vol II, World Press 2. Cooray TMJA(2008) Applied Time Series, Analysis and forecasting, Narosa Publishing house 3. Chatfield C (2004) Analysis of Time Series, Chapman & Hall 4. Cryer, J.D. and Chan, K-S: Time Series Analysis with applications in R 5. P.Brockwell & R.A.Davis : Introduction to time series and forecasting 6. Mukhopadhyay P. : Applied Statistics

Skill Enhancement Elective papers in Statistics

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
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 list	1. The R Cookbook, by Paul Teetor 2. The R Graphics Cookbook, by Winston Chang 3. Data Manipulation with R, by Phil Spector 4. The R Inferno, by Patrick Burns (freely available at http://www.burns-stat.com/pages/Tutor/R_inferno.pdf) 5. simpleR, by John Verzani (freely available at https://cran.r-project.org/doc/contrib/Verzani-SimpleR.pdf) 6. 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
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 list	1. Moore, D.S. and McCabe, G.P. and Craig, B.A. (2014): Introduction to the Practice of Statistics, W.H. Freeman 2. 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
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 list	1. Shonkwiler, Ronald W. and Mendivil, Franklin (2009): Explorations in Monte Carlo Methods (Undergraduate Texts in Mathematics) 2. Carsey, Thomas M. and Harden, Jeffrey J. (2014): Monte Carlo Simulation and Resampling Methods for Social Science. 3. Data Manipulation with R, by Phil Spector 4. John M. Chambers, Software for Data Analysis: Programming with R 5. S. Ross : Simulation

Semester	**FOUR**
Paper Number	**STAT04SEE2B**
Paper Title	**Research Methodology**
No. of Credits	**4**
No. of classes	Theory: 4 Practical: 4
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 list	1. Kothari, C.R. (2009): Research Methodology: Methods and Techniques, 2nd Revised Edition reprint, New Age International Publishers. 2. Kumar, R (2011): Research Methodology: A Step - by - Step Guide for Beginners, SAGE publications. 3. Booth , W.C., Colomb, G.G. and Williams, J. M., The Craft of Research,

	3rd edition, University of Chicago Press. 4. Alley, M., The Craft of Scientific Writing, 3rd edition, Springer, 1996.

Discipline Specific Elective Papers in Statistics

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.

Group-1	
Paper Number	**01**
Paper Title	**Stochastic Processes and Queuing Theory**
No. of classes	Theory: 4 Practical:4
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 Markov chain, Markov chain as graphs, Generalization of independent Bernoulli trials, classification of states and chains, stability of Markov system. **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	1. Calculation of transition probability matrix. 2. Identification of characteristics of reducible and irreducible chains. 3. Identification of types of classes. 4. Identification of ergodic transition probability matrix 5. Stationarity of Markov chain. 6. Computation of probabilities in case of generalizations of independent Bernoulli trials. 7. Calculation of probabilities for given birth and death rates and vice versa. 8. Calculation of probabilities for Birth and Death Process. 9. Calculation of probabilities for Yule Furry Process. 10. Computation of inter-arrival time for a Poisson process. 11. Calculation of Probability and parameters for (M/M/1) model and change in behaviour of queue as N tends to infinity.
Reading/Reference	

Lists	1. P. G. Hoel, S. C. Port and C. J. Stone: Introduction to Stochastic Processes 2. Medhi, J. (2009): Stochastic Processes, New Age International Publishers. 3. S. Karlin and H.M.Taylor: A first course in stochastic process. 4. S. Ross: Stochastic Process 5. J. G. Kemeny, J. L. Snell and A. W. Knapp: Finite Markov Chains. 6. Bhat,B.R.(2000): Stochastic Models: Analysis and Applications, New Age International Publishers. 7. Taha, H. (1995): Operations Research: An Introduction, Prentice- Hall India. 8. Feller, William (1968): Introduction to probability Theory and Its Applications, Vol I, 3rd Edition, Wiley International. 9. R. N. Bhattacharya and E. Waymire: Stochastic Process and Applications.

Group-1	
Paper Number	**02**
Paper Title	**Econometrics**
No. of Credits	**6**
No. of classes	Theory: 4 Practical: 4
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.* 1. Fitting of ordinary linear regression equations with diagnostics. 2. Tests of heteroscedasticity. 3. Fitting of regression equation after making adjustments for heteroscedasticity. 4. Tests of autocorrelation. 5. Fitting of regression equation after making adjustments for autocorrelation. 6. Tests of multicollinearity. 7. Fitting of regression equation after making adjustments for multicollinearity.
Reading/Reference Lists	1. G.S. Maddala: Introduction to Econometrics 2. D.N. Gujarati: Basic Econometrics 3. J. Johnston and J. Dinardo: Econometric Methods

Group-1	
Paper Number	**03**
Paper Title	**Advanced Statistical Methods**
No. of Credits	**6**
No. of classes	Theory: 4 Practical: 4
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.* 1. Case study using linear regression to demonstrate the inferential aspects. 2. Simulation of bias, variance and prediction error in case of linear regression. 3. Plotting the prediction error, bias and variance as function of tuning parameters through simulation (for all linear smoothers). 4. K- fold cross validation to estimate the error in linear smoothers. 5. Fitting of K-NN, Kernel regression and spline models. 6. Kernel density estimates 7. Jackknife and Bootstrap 8. Standard applications of EM algorithm. 9. Visualization of circular data. 10. Summary measures of circular data 11. Regression for circular data.
Reading/Reference Lists	1. Larry Wasserman: All of Non-parametric Statistics 2. Gareth James et.al.: Introduction to Statistical Learning (with applications in R) 3. Györfi, László, et. al.: A Distribution-Free Theory of Nonparametric Regression. 4. Simonoff, Jeffrey S. (1996). Smoothing Methods in Statistics. 5. Davison, A. C. and D. V. Hinkley (1997). Bootstrap Methods and their Applications 6. B.Efron : The Jackknife, the Bootstrap and other Sampling Plans 7. D.Rubin & R.J.A. Little : Statistical Analysis with Missing Data 8. S. Rao Jammalamadaka, A. Sengupta : Topics in Circular Statistics 9. Mardia, K and Jupp, P.E. : Directional Statistics 10. Fisher, N. I.: Statistical Analysis of Circular Data

Group-2	
Paper Number	**01**
Paper Title	**Survival Analysis and Biostatistics**
No. of Credits	**6**
No. of classes	Theory: 4 Practical: 4
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.* 1. To estimate survival function 2. To determine death density function and hazard function 3. To identify type of censoring and to estimate survival time for type I censored data 4. To identify type of censoring and to estimate survival time for type II censored data 5. To identify type of censoring and to estimate survival time for progressively type I 6. censored data 7. Estimation of mean survival time and variance of the estimator for type I censored data 8. Estimation of mean survival time and variance of the estimator for type II censored data 9. Estimation of mean survival time and variance of the estimator for progressively type I censored data 10. To estimate the survival function and variance of the estimator using Non-parametric methods with Actuarial methods 11. To estimate the survival function and variance of the estimator using Non-parametric methods with Kaplan-Meier method 12. To estimate Crude probability of death 13. To estimate Net-type I probability of death 14. To estimate Net-type II probability of death 15. To estimate partially crude probability of death 16. To simulate the random sequence of treatment assignments. 17. To plot the probability of imbalance. 18. To simulate the treatment allocation ratio.
Reading/Reference Lists	1. Lee, E.T. and Wang, J.W. (2003): Statistical Methods for Survival data Analysis, 3rd Edition, John Wiley and Sons. 2. Biswas, S. (2007): Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, Reprinted 2ndCentral Edition, New Central Book Agency. 3. Chiang, C.L. (1968): Introduction to Stochastic Processes in Bio Statistics,

	JohnWiley and Sons. 4. Indrayan, A. (2008): Medical Biostatistics, 2nd Edition Chapman and Hall/CRC. 5. Rosenberger and Lachin: Randomized Clinical Trials: Theory and Practice 6. Ding-Geng (Din) Chen and Karl E. Peace: Clinical Trial Data Analysis Using R

Group-2	
Paper Number	**02**
Paper Title	**Advanced Mathematical Analysis**
No. of Credits	**6**
No. of classes	Theory: 5 Tutorial:1
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	1. W. Rudin : Principles of Mathematical Analysis 2. G.F. Simmons: Introduction to Topology and Modern Analysis 3. S. Kumaresan : Topology of Metric Spaces 4. S. Shirali and H.L.Vasudeva : Metric Spaces 5. A. Chakraborty : Metric Space 6. J. C. Burkill and H. Burkill: A second course in Mathematical Analysis 7. J.B. Conway : Functions of one complex variable.

	8. I.N. Herstein : Topics in Algebra 9. Sen, Ghosh, Mukhopadhay : Topics in Abstract Algebra 10. M. Artin : Algebra

Group-2	
Paper Number	**03**
Paper Title	**Operations Research**
No. of Credits	**6**
No. of classes	Theory: 4 Practical: 4
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. **35L** **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** Inventory Management: ABC inventory system, characteristics of inventory system. EOQ Model and its variations, with and without shortages, Quantity Discount Model with price breaks. **31L**
List of Practical (Using TORA/WINQSB/LINGO)	1. Mathematical formulation of L.P.P and solving the problem using graphical method, Simplex technique and Charne's Big M method involving artificial variables. 2. Identifying Special cases by Graphical and Simplex method and interpretation 1. Degenerate solution 2. Unbounded solution 3. Alternate solution 4. Infeasible solution 3. Allocation problem using Transportation model. 4. Allocation problem using Assignment model. 5. Problems based on game matrix. 6. Graphical solution to mx2 / 2xn rectangular game.

	7. Mixed strategy. 8. To find optimal inventory policy for EOQ models and its variations. 9. To solve all-units quantity discounts model.
Reading/Reference Lists	1. Taha, H. A. (2007): Operations Research: An Introduction, 8 Hall of India. 2. KantiSwarup, Gupta, P.K. and Manmohan (2007): Operations Research, 13th Edition, Sultan Chand and Sons. 3. Hadley, G: (2002) : Linear Programming, Narosa Publications 4. Hillier, F.A and Lieberman, G.J. (2010): Introduction to Operations Research-Concepts and cases, 9th Edition, Tata McGraw Hill

Group-2	
Paper Number	**04**
Paper Title	**Project Work**
No. of Credits	**6**
No. of classes	**8**
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 area of human interest. The project work will provide hands on training to the students to deal with data emanating from some real life situation and propel them to dwell on some theory or relate it to some theoretical concepts.

Generic Elective

Semester	**One**
Paper Number	**STAT01GE01**
Paper Title	**Statistical Methods**
No. of Credits	**6**
No. of classes	Theory: 4 Practical: 4
Syllabus	**Unit 1** Introduction: Definition and scope of Statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, variables, scales of measurement - nominal,ordinal, interval and ratio. Presentation: tabular and graphic, including histogram and ogives. **35L** **Unit 2** Measures of Central Tendency: mathematical and positional. Measures of Dispersion: range,quartile deviation, mean deviation, standard deviation, coefficient of variation, moments,skewness and kurtosis. **40L** **Unit 3** Bivariate data: Definition, scatter diagram, simple, partial and multiple correlation (3 variables only), rank correlation. Simple linear regression, principle of least squares andfitting of polynomials and exponential curves. **30L** **Unit 4** Theory of attributes, consistency of data, independence and association of attributes,measures of association and contingency. **23L**
List of Practical	1. Graphical representation of data 2. Problems based on measures of central tendency 3. Problems based on measures of dispersion 4. Problems based on combined mean and variance and coefficient of variation 5. Problems based on moments, skewness and kurtosis 6. Fitting of polynomials, exponential curves 7. Karl Pearson correlation coefficient 8. Partial and multiple correlations 9. Spearman rank correlation with and without ties. 10. Correlation coefficient for a bivariate frequency distribution 11. Lines of regression, angle between lines and estimated values of variables. 12. Checking consistency of data and finding association among attributes.
Reading/ Reference list	1. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I& II, 8th Edn. The World Press, Kolkata. 2. Das, N.G.: Statistical Methods, Vol I and II, Tata McGraw HillPub. Co. Ltd. 3. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical

	Statistics with Applications, (7th Edn.), Pearson Education, Asia. 4. 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.

Semester	**Two**
Paper Number	**STAT02GE02**
Paper Title	**Introductory Probability**
No. of Credits	**6**
No. of classes	Theory: 4 Practical: 4
Syllabus	**UNIT I** Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications. **38L** **UNIT II** Random Variables: Discrete and continuous random variables, p.m.f., p.d.f. ,c.d.f. Illustrations of random variables and its properties. Expectation, variance, moments and moment generating function. **30L** **UNIT III** Convergence in probability, almost sure convergence, Chebyshev's inequality, weak law of large numbers, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorem (C.L.T.). **20L** **UNIT IV** Standard probability distributions: Binomial, Poisson, geometric, negative binomial, hypergeometric, uniform, normal, exponential, beta, gamma. **40L**

List of Practical	1. Fitting of binomial distributions for n and p = q = ½ given 2. Fitting of binomial distributions for n and p given 3. Fitting of binomial distributions computing mean and variance 4. Fitting of Poisson distributions for given value of lambda 5. Fitting of Poisson distributions after computing mean 6. Application problems based on binomial distribution 7. Application problems based on Poisson distribution 8. Problems based on area property of normal distribution 9. To find the ordinate for a given area for normal distribution 10. Application based problems using normal distribution 11. Fitting of normal distribution when parameters are given 12. Fitting of normal distribution when parameters are not given
Reading/ Reference list	1. Goon A.M., Gupta M.K. and Dasgupta B. (2002): An Outline of Statistical Theory, Vol. I , The World Press, Kolkata. 2. Das, N.G.: Statistical Methods, Vol I and II, Tata McGraw Hill Pub. Co. Ltd. 3. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi. 4. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia. 5. Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi

Semester	**Three**
Paper Number	**STAT03GE03**
Paper Title	**Basics of Statistical Inference**
No. of Credits	**6**
No. of classes	Theory: 4 Practical: 4
Syllabus	**UNIT I** Estimation of population mean, confidence intervals for the parameters of a normal distribution (one sample and two sample problems). The basic idea of significance test. Null and alternative hypothesis. Type I & Type II errors, level of significance, concept of p-value. Tests of hypotheses for the parameters of a normal distribution (one sample and two sample problems). **40L** **UNIT II** Categorical data: Tests of proportions, tests of association and goodness-of-fit using Chi-square test, Yates' correction. **25L**

	UNIT III Tests for the significance of correlation coefficient. Sign test for median, Sign test for symmetry, Wilcoxon two-sample test. **20L** **UNIT IV** Analysis of variance, one-way and two-way classification. Brief exposure of three basic principles of design of experiments, treatment, plot and block. Analysis of completely randomized design, randomized complete block design. **43L**
List of Practical	1. Estimators of population mean. 2. Confidence interval for the parameters of a normal distribution (one sample and two sample problems). 3. Tests of hypotheses for the parameters of a normal distribution (one sample and two sample problems). 6. Chi-square test of proportions. 7. Chi-square tests of association. 8. Chi-square test of goodness-of-fit. 9. Test for correlation coefficient. 10. Sign test for median. 11. Sign test for symmetry. 12. Wilcoxon two-sample test. 13. Analysis of Variance of a one way classified data 14. Analysis of Variance of a two way classified data. 15. Analysis of a CRD. 16. Analysis of an RBD.
Reading/ Reference list	1. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I& II, 8th Edn. The World Press, Kolkata. 2. Das, N.G.: Statistical Methods, Vol I and II, Tata McGraw Hill Pub. Co. Ltd. 3. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals Of Mathematical Statistics, Sultan Chand & Sons 4. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi. 5. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia. 6. Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi

Semester	**Four**
Paper Number	**STAT04GE04**
Paper Title	**Applied Statistics**
No. of Credits	**6**
No. of classes	Theory: 4 Practical: 4
Syllabus	**UNIT I** Economic Time Series: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series. Measurement of trend by method of free-hand curve, method of semi-averages and method of least squares (linear, quadratic and modified exponential).Measurement of seasonal variations by method of ratio to trend. **30L** **UNIT II** Index numbers: Definition, Criteria for a good index number, different types of index numbers. Construction of index numbers of prices and quantities, consumer price index number. Uses and limitations of index numbers. **26L** **UNIT III** Statistical Quality Control: Importance of statistical methods in industrial research and practice. Determination of tolerance limits. Causes of variations in quality: chance and assignable. General theory of control charts, process & product control, Control charts for variables: X- bar and R-charts. Control charts for attributes: p- and c-charts. **36L** **UNIT IV** Demographic Methods: Introduction, measurement of population, rates and ratios of vital events. Measurement of mortality: CDR, SDR (w.r.t. Age and sex), IMR, Standardized death rates. Life (mortality) tables: definition of its main functions and uses. Measurement of fertility and reproduction: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR. **36L**

List of Practical	1. Measurement of trend: Fitting of linear, quadratic trend, exponential curve and plotting of trend values and comparing with given data graphically. 2. Measurement of seasonal indices by Ratio-to-trend method and plotting of trend values and comparing with given data graphically. 3. Construction of price and quantity index numbers by Laspeyres' formula, Paasche's formula, Marshall-Edgeworth's formula, Fisher's Formula - Comparison and interpretation. 4. Construction of wholesale price index number, fixed base index number and consumer price index number with interpretation 5. Construction and interpretation of X bar & R-chart 6. Construction and interpretation p-chart (fixed sample size) and c-chart 7. Computation of measures of mortality 8. Completion of life table 9. Computation of measures of fertility and population growth
Reading/ Reference list	1. Mukhopadhyay, P. (1999): Applied Statistics, New Central Book Agency, Calcutta. 2. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition World Press, Kolkata. 3. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals Of Applied Statistics, 4th Edition(Reprint), Sultan Chand & Sons 4. Das, N.G.: Statistical Methods, Vol I and II, Tata McGraw Hill Pub. Co. Ltd. 5. Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.

PRESIDENCY
UNIVERSITY
KOLKATA

Presidency University, Kolkata
Syllabus
in
M.Sc. Statistics
Semesters 7 – 10
(With Effect from Academic Session 2021 – 2022)

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

	STAT1092 : Research Project	21
	List of Topics to be Covered under Elective/Special Courses/Papers	
	Visualization and Analysis of Big and Complex Data	
	Data Analysis Using Python and C/C++	
	Advanced Mathematics	
	Analysis of Directional Data and Data on Manifolds	
	Statistics on Graphs and Networks	
	Analysis of High Dimensional Data	
	Machine Learning : Theory and Methods	
	Optimization Techniques and Operations Research/Convex Optimization	
	Advanced Sample Survey	
	Advanced Design of Experiments	
	Advanced Reliability Theory	
	Advanced Survival Analysis	
	Advanced Clinical Trials and Bioassay	
	Statistical Genetics and Epidemiology	
	Actuarial Statistics	
	Applied Stochastic Processes	
	Stochastic Calculus and Financial Engineering	
	Functional Data Analysis and Topological Data Analysis	
	Signal, Image, Video Data Processing and Analysis	
	Data Mining	

1.1 Academic Sessions :
Odd Semester : Semester Seven/Nine
Even Semester : Semester Eight/Ten

1.2 Major Courses/Papers

STAT0701 : Mathematics I	SEM 7
STAT0702 : Probability I	SEM 7
STAT0703 : Inference I	SEM 7
STAT0801 : Mathematics II	SEM 8
STAT0802 : Probability II	SEM 8
STAT0803 : Inference II	SEM 8
STAT0901 : Stochastic Processes	SEM 9
STAT0902 : Decision Theory and Bayesian Inference	SEM 9
STAT0903 : Inference III	SEM 9
STAT1001 : Special Paper	SEM 10
STAT1002 : Special Paper	SEM 10
STAT1003 : Research Methodology Nonparametric and Sequential Inference	SEM 10

1.3 Practical/Sessional Courses/Papers

STAT0791 : Regression I	SEM 7
STAT0792 : Statistical Computing	SEM 7
STAT0891 : Regression II	SEM 8
STAT0892 : Sample Survey and Design of Experiments	SEM 8
STAT0991 : Analysis of Time Series and Spatial Data	SEM 9
STAT0992 : Applied Multivariate Analysis and Resampling	SEM 9
STAT1091 : Combined Lab for **STAT1001, STAT1002** and **STAT1003**	SEM 10
STAT1092 : Project	SEM 10

In the tenth semester, a student will have to choose two special papers and the project, which is compulsory. Before the commencement of the semester, the department will announce the particular special paper(s) that may be offered depending upon the availability of faculty and resources.

Scheme for Courses in M.Sc. Statistics

1.4 Credit Distribution across Courses

Course Type	Total Papers	Credits (Theory+Practical)
Major Courses/Papers	12	12×4+12x0 = 48
Practical/Sessional Courses/Papers	8	8×2+8×2 = 32
Total	20	80

1.5 Scheme for M.Sc. Curriculum

Semester	Course/Paper	Paper Code	Course Name	IA Marks	Semester Marks	Total Marks
VII	Major Course - 17	STAT0701	Mathematics I	15	35	50
	Major Course - 18	STAT0702	Probability I	15	35	50
	Major Course - 19	STAT0703	Inference I	15	35	50
	Practical/Sessional Course - 9	STAT0791	Regression I	0	50	50
	Practical/Sessional Course - 10	STAT0792	Statistical Computing	0	50	50
VIII	Major Course - 20	STAT0801	Mathematics II	15	35	50
	Major Course - 21	STAT0802	Probability II	15	35	50
	Major Course - 22	STAT0803	Inference II	15	35	50
	Practical/Sessional Course - 11	STAT0891	Regression II	0	50	50
	Practical/Sessional Course - 12	STAT0892	Sample Survey and Design of Experiments	0	50	50
IX	Major Course - 23	STAT0901	Stochastic Processes	15	35	50
	Major Course - 24	STAT0902	Decision Theory and Bayesian Inference	15	35	50
	Major Course - 25	STAT0903	Inference III	15	35	50
	Practical/Sessional Course - 13	STAT0991	Analysis of Time	0	50	50

			Series and Spatial Data			
	Practical/Sessional Course - 14	STAT0992	Applied Multivariate Analysis and Resampling	0	50	50
X	Major Course - 26	STAT1001	Special Paper	15	35	50
	Major Course - 27	STAT1002	Special Paper	15	35	50
	Major Course - 28	STAT1003	**Research Methodology** Nonparametric and Sequential Inference	15	35	50
	Practical/Sessional Course - 15	STAT1091	Combined Lab for **STAT1001, STAT1002** and **STAT1003**	0	50	50
	Practical/Sessional Course - 16	STAT1092	Project	0	50	50

N.B:-
1. The lecture hours calculation in all the papers includes 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.

Lecture Hours Calculations:

1 credit of Theory / Tutorial = 1 Lecture
1 credit of Practical = 2 Lectures
Maximum number of effective class-weeks in a semester (excluding internal exams): 12 weeks
(Two weeks for mid-semester examination and sessional examination)

Total number of Lectures for a paper in a semester

Course	Credits (Theory+Practical)	Classes/week	Total lectures/semester
Major	4+0	(4×1) + (0×2)	48
Practical/Sessional	2+2	(2×1) + (2×2)	72

2.

Detailed Syllabus of Courses in M.Sc. Statistics

Semester	**SEVEN**
Paper	**Major Course - 17**
Paper Code	**STAT0701**
Paper Title	**Mathematics I**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Recap of Functions, Cardinality of Sets, Cantor's Theorem. Field and Order properties of real numbers, The Completeness Axiom of R, Archimedean property, Origin of Irrational numbers, Comparison of R and Q, Denseness of Rational numbers in R.
	Unit 2 Recap of Sequence and Series of real numbers, tests of convergence, rearrangement of series and Riemann's theorem (without proof) and its importance. Limits and Continuity, Properties of Continuous functions. Uniform and absolute continuity.
	Unit 3 Recap of Differentiation, Rolle's theorem and mean value theorem,Taylor series with remainder and infinite Taylor series. Recap of Riemann Integration, First and Second Fundamental theorems of Integral Calculus, Mean Value theorem for Integrals.
	Unit 4 Definition of metric space, Examples, Some Topological aspects, Convergence of Sequences in metric spaces, Cauchy Sequences and Completeness, Continuity and Uniform Continuity, Compactness, Heine-Borel Theorem.
Reading/ Reference Lists	Bartle, R. G. & Sherbert, D. R. : Introduction to Real Analysis Apostol, T.M. : Mathematical Analysis Rudin, W. : Principles of mathematical analysis Malik, S.C. & Arora, S. : Mathematical Analysis Kumaresan, S. : A Basic Course in Real Analysis Chakraborty, A. : Real Analysis, volumes 1,2,3 (2014), second edition, Sarat Book House. Simmons, G. F. : Introduction to Topology and Modern Analysis

Semester	**SEVEN**
Paper	**Major Course - 18**
Paper Code	**STAT0702**
Paper Title	**Probability I**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0

Syllabus	**Unit 1** Axiomatic definition of probability. Different classes of sets – semifield, field, sigma-field, Borel sigma-field, extension of measure from semifield to field. Good Sets principle, Caratheodory's extension and extension of measure from field to sigma-field.
	Unit 2 Cumulative distribution function and one to one correspondence between CDF and probability measures on Borel sigma-field on R. CDF and probability measures on Borel sigma-field on Rn. Measurable functions (random variables), basic properties, sigma-fields generated by functions, Lebesgue integration of measurable functions, properties of integrals, relation between Riemann and Lebesgue integral, Monotone convergence theorem, Fatou's Lemma, Dominated convergence theorem.
	Unit 3 Product measures, classical and general version of product measure theorem, Fubini's theorem (statement only), countable and uncountably infinite product of probability spaces and product measure theorem on them, Kolmogorov consistency theorem (statement only).
	Unit 4 Absolute continuity, singularity of measures, Radon-Nikodym theorem (statement only), Lebesgue decomposition (statement only).
Reading/ Reference Lists	Ash, R. B. & Doleans-Dade, C. A. : Probability and Measure Theory Chung, K. L. : A Course in Probability Theory Billingsley, P. : Probability and Measure Chow, Y. S. & Teicher, H. : Probability Theory Durrett, R. : Probability: Theory and Examples

Semester	**SEVEN**
Paper	**Major Course - 19**
Paper Code	**STAT0703**
Paper Title	**Inference I**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Review of concept of population and sample, family of probability measures, parameter and statistic, problems of inference. Exponential family, location and scale families.
	Unit 2 Non-central $\chi 2$, t & F distributions – definitions and selected properties. Distribution of quadratic forms – Cochran's theorem. Sampling from Multivariate normal distribution – independence of sample mean vector and variance covariance matrix. Wishart distribution. Distributions of partial and multiple correlation coefficients and regression coefficients, distribution of intraclass correlation coefficient.
	Unit 3 Review of Sufficiency principle, Minimal Sufficiency, Complete and boundedly complete families, Ancillarity and Basu's Theorem. Fisher information in case of single and multiple parameters, Cramer-Rao lower bound, Bhattacharya system of bounds. Review of unbiased estimation, Rao-Blackwell and Lehmann-Scheffe Theorems, Minimum Variance Unbiased Estimators and related problems.
	Unit 4 Review of methods of estimation, Maximum likelihood estimation in case of multivariate normal, Shrinkage Estimators of mean - James Stein's Estimate.

	Invariance estimation.
Reading/ Reference Lists	Lehmann. E.L., Casella, G. : Theory of Point Estimation Casella , G. and Berger R.L. : Statistical Inference Bickel, P.J., Doksum, K.A.: Mathematical Statistics: Basic Ideas and Selected Topics, Volume 1 Zacks, S : The Theory of Statistical Inference Rao, C.R. : Linear Statistical Inference and its Applications Shao, J. : Mathematical Statistics Anderson, T.W. : An Introduction to Multivariate Analysis. Khirsagar, A.M. : Multivariate Analysis Wilks, S.S.: Mathematical Statistics.

Semester	**EIGHT**
Paper	**Major Course - 20**
Paper Code	**STAT0801**
Paper Title	**Mathematics II**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	
	Unit 1 Sequences of real valued functions, Notions of Pointwise and Uniform convergence, Series of functions, Power series and their convergence. Weierstrass approximation theorem (without proof). Interchange of order of derivative and limits, Interchange of order of integration and limits.
	Unit 2 Partial Derivative, Directional derivative and Total derivative, Multivariate Taylor series expansion. Leibnitz theorem. Maxima and minima of multivariable functions.
	Unit 3 Recap of axiomatic approach to vector spaces, inner product space and normed linear space. Orthogonal polynomials, Fourier series representation of real and complex valued functions, Fourier series as best approximation, recovery of periodic functions using Fourier series, Carleson's theorem. Derivation of Fourier series of standard functions and related problems. Application of Fourier transform and Laplace transform.
	Unit 4 Concept of classical function spaces and sequence spaces. Banach space and Hilbert space.Complete orthonormal system (CONS), Reisz representation theorem (statement and application only), projection on Hilbert sub spaces and its properties. Lp space of random variables. L2 space of random variables and projection **-** illustrations using regression and other statistical examples.
Reading/ Reference Lists	Bartle, R. G. & Sherbert, D. R.: Introduction to Real Analysis Apostol, T.M. : Mathematical Analysis Rudin, W. : Principles of mathematical analysis

	Malik, S.C. & Arora, S. : Mathematical Analysis Kumaresan, S : A Basic Course in Real Analysis Chakraborty, A. : Real Analysis, volumes 1,2,3, second edition (2014), Sarat Book House. Rao, A.R. & Bhimasankaram, P. : Linear Algebra Folland, G.B. : Fourier Analysis and Its Applications Tolstov, G. P. : Fourier Series Stein, E. M., Stein, M. Shakarchi, R. : Fourier Analysis An Introduction Simmons, G. F. : Introduction to Topology and Modern Analysis Conway, J. B. : A Course in Functional Analysis Kreyszig, E. : Introductory Functional Analysis with Applications Rudin, W. : Functional Analysis

Semester	**EIGHT**
Paper	**Major Course - 21**
Paper Code	**STAT0802**
Paper Title	**Probability II**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Characteristic functions and its basic properties, inversion formula, Levy's continuity theorem. Kolmogorov's maximal inequality, Chebyshev's, Holder's and Minkowski's inequalities., Lp spaces. limsup, liminf and limit of sets, continuity from above and below, Borel-Cantelli two lemmas, Kolmogorov 0-1 law, sequence of random variables.
	Unit 2 Different modes of convergence and their interrelationships, properties and alternative characterizations, Slutsky's theorem, uniform convergence, Polya's theorem, Scheffe's theorem, Frechet-Shohat theorem (without proof), continuous mapping theorem, Uniform Integrability. Law of convergence of types, asymptotic normality, Cramer-Wold device, Skorohod representation theorem (application only).
	Unit 3 SLLN, WLLN, Lp-LLN, classical limit theorems, Different limit theorems for independent random variables and double arrays of random variables, partial sums of random variables and Kolmogorv 2 series and 3 series theorem.
	Unit 4 Introduction to discrete time stochastic process, discrete time discrete state space Markov chain, Chapman-Kolmogorov equation, renewal equation, classification of states, stationary distribution, limit distribution, ergodicity, null and positive recurrence, periodicity.
Reading/ Reference Lists	Ash, R. B. & Doleans-Dade, C. A. : Probability and Measure Theory Chung, K. L. : A Course in Probability Theory Billingsley, P. : Probability and Measure Chow, Y. S. & Teicher, H. : Probability Theory Durrett, R. : Probability: Theory and Examples Goswami, A. & Rao, B. V. : A course in applied stochastic process Medhi, J. : Stochastic Processes

Semester	**EIGHT**
Paper	**Major Course - 22**
Paper Code	**STAT0803**
Paper Title	**Inference II**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	
	Unit 1 Review of basic concepts of testing of hypothesis and confidence interval. Review of small sample exact tests and related confidence intervals, Beherens-Fisher problem (Scheffe's solution), likelihood ratio test and asymptotic chi-square tests. Wald's test and Rao's Score test. Review of F test for general linear hypothesis in case of linear models. Application of ANOVA technique in general linear hypothesis. Hotelling T-squared tests and related confidence sets, Union-intersection principle and its application.
	Unit 2 Review of notions of nonrandomized and randomized tests. Fundamental Neyman Pearson Lemma (Proof: Existence, Sufficiency and Necessity parts) and its generalization (Sufficiency part only), UMP Tests and related problems, Monotone Likelihood ratio.
	Unit 3 UMPU Tests: One parameter exponential family (without derivation), Locally best tests(Concepts only) Similar tests, Neyman structure, UMPU tests for composite hypotheses and related problems, Invariant tests: UMPI (concepts only).
	Unit 4 Interval estimation : Confidence sets based on pivot, relation with hypothesis testing, UMA and UMAU confidence sets.
Reading/ Reference Lists	Lehmann. E.L., Romano, J. : Testing statistical hypotheses. Casella , G. and Berger R.L. : Statistical Inference Bickel, P.J., Doksum, K.A.: Mathematical Statistics: Basic Ideas and Selected Topics, Volume 1 Zacks, S : The Theory of Statistical Inference Rao, C.R. : Linear Statistical Inference and its Applications Shao, J. : Mathematical Statistics Anderson, T.W. : An Introduction to Multivariate Analysis. Giri, N.C.: Multivariate Statistical Analysis. Seber, G.A.F and Lee, A.J. : Linear regression analysis.

Semester	**NINE**
Paper	**Major Course - 23**
Paper Code	**STAT0901**
Paper Title	**Stochastic Processes**
No. of Credits	**4**

No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Branching process, Introduction to continuous time stochastic process. Continuous time markov chains with discrete state space, Kolmogorov equations (applications only), birth and death chains, applications to queuing theory, busy period analysis, network of queues.
	Unit 2 Poisson process, equivalence of various constructions, basic properties, conditional distribution of arrival times given number of events and its applications, compound Poisson process, nonhomogeneous Poisson process, Poisson process on plane (concepts only).
	Unit 3 Introduction to Brownian motion, Kolmogorv continuity theorem, Donsker's invariance principle, other construction of Brownian motion, Brownian bridge, supremum of Brownian bridge and its application to goodness of fit tests.
	Unit 4 Conditional expectation and conditional probability distribution. Regular conditional probability (concept only). Discrete parameter martingales, sub-and super-martingales, martingale convergence theorem, reverse martingales, Stopping times, applications of martingale theory.
Reading/ Reference Lists	Ross, S. : Stochastic Processes Hoel, Port & Stone : Stochastic Processes Karlin, S. & Taylor, H. M. : Stochastic Processes Harris : Branching Processes: Harris Chow,Y. S. & Teicher, H. : Probability Theory Breiman, L. : Probability Theory Morters, P. & Peres, Y. : Brownian Motion Nevue, J. : Discrete Parameter Martingales Hall, P. & Heyde, C. C. : Martingale Limit Theory and its Application

Semester	**NINE**
Paper	**Major Course - 24**
Paper Code	**STAT0902**
Paper Title	**Decision Theory and Bayesian Inference**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Decision Problem and two-person game, nonrandomized and randomized rules, risk function, admissibility of decision rules, complete, essentially complete, minimal complete and minimal essentially complete classes. Essential completeness and completeness of class of rules based on sufficient statistic and the class of nonrandomized rules for convex loss.
	Unit 2 Bayes rules, extended Bayes, generalized Bayes and limit of Bayes rules, admissibility of Bayes rule, minimax rules, method for finding minimax rules.
	Unit 3 Bayesian Inference – difference with classical approach, point estimation and credible

	sets. Predictive distributions. Illustration with examples of one-parameter and multiparameter models using conjugate and noninformative priors. Bayesian testing and model selection. BIC. Objective Bayes factors, intrinsic priors.
	Unit 4 Bayesian variable selection, comparison of p-value and posterior probability of H0 as measures of evidence. Bayesian p-value. Bayesian approaches to some common problems in inference including linear regression. Hierarchical and empirical Bayes. Brief discussions on Bayesian computational techniques and their applications : Gibbs sampler and MH algorithm.
Reading/ Reference Lists	Ferguson, T. S. : Mathematical Statistics Berger, J. O. : Statistical Decision Theory and Bayesian Analysis Lehmann, E. L. : Theory of Point Estimation Robert, C. P. : The Bayesian Choice Ghosh, J. K., Delampady, M. & Samanta, T. : An Introduction to Bayesian Analysis: Theory and Methods. Lee, P. : Bayesian Statistics – An Introduction Congdon, P. : Bayesian Statistical Modelling (2nd Edition) Gelman, et.al. : Bayesian Data Analysis (3rd Edition). Hoff, P. D. : A First Course in Bayesian Statistical Methods.

Semester	**NINE**
Paper	**Major Course - 25**
Paper Code	**STAT0903**
Paper Title	**Inference III**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Asymptotic distribution of transformed statistics. Multivariate delta method and variance stabilizing formula and applications, asymptotic distribution of order statistics including extreme order statistics and sample quantiles. Asymptotic representation of sample quantiles.
	Unit 2 Large sample properties of maximum likelihood estimates and the method of scoring. Pearson's chi-square statistic. Chi-square and likelihood ratio test statistics for simple hypotheses related to contingency tables. Heuristic proof for composite hypothesis with contingency tables as examples. Brief introduction to asymptotic efficiency of estimators. ARE for comparison of tests.
	Unit 3 Basic idea of robustness, measures of robustness – breakdown points, influence function, sensitivity curve, M estimators, influence function of M estimators, different statistical models and associated robust statistics.
	Unit 4 Multiple comparison problem, simultaneous confidence intervals in linear models, multiple comparison tests in linear models, Tukey’s HSD, Fisher’s LSD, Scheffe’s test. Bonferroni correction, FDR and FWER with applications.
Reading/ Reference Lists	R.J.Serfling : Approximation Theorems of Mathematical Statistics E.L.Lehmann : Large Sample Theory C.R.Rao : Linear Statistical Inference and its Applications

	Jun Shao : Mathematical Statistics A. Dasgupta : Asymptotic Theory of Statistics and Probability I.A. Ibragimov, R. Z. Has'minskii : Statistical Estimation : Asymptotic Theory A. W. Van der Vaart : Asymptotics Statistics Jana Jureckova, Pranab Sen, Jan Picek : Methodology in Robust and Nonparametric Statistics Peter J. Huber, Elvezio M. Ronchetti : Robust Statistics Thorsten Dickhaus : Simultaneous Statistical Inference

Semester	**TEN**
Paper	**Major Course - 26**
Paper Code	**STAT1001**
Paper Title	**Special Paper**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1**
	Unit 2
	Unit 3
	Unit 4
Reading/ Reference Lists	

Semester	**TEN**
Paper	**Major Course - 27**
Paper Code	**STAT1002**
Paper Title	**Special Paper**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1**
	Unit 2
	Unit 3
	Unit 4
Reading/	

Reference Lists	

Semester	**TEN**
Paper	**Major Course - 28**
Paper Code	**STAT1003**
Paper Title	**Research Methodology** Nonparametric and Sequential Inference
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Empirical distribution function, Glivenko-Cantelli theorem, DKW inequality, VC theory, empirical likelihood, regular statistical functional, U-statistics, strong, weak consistency and limit theorem of U-statistics, degeneracy, V-statistics, plug-in estimators and nonparametric delta method, R-estimators, linear rank statistics and rank limit theorems.
	Unit 2 Tests of location and symmetry : one-sample and two-sample problems, Two-sample scale problem, bivariate sign test, test of randomness, one-sample and two-sample KS test, Cramer von-Mises test.
	Unit 3 Concept of sequential procedures, Wald's fundamental and generalized identity, random walk procedure.
	Unit 4 Concept of OC and ASN, SPRT and its properties, optimality of SPRT (under usual approximation), sequential estimation.
Reading/ Reference Lists	Hajek, J. & Sidek, Z. : Theory of Rank Tests Randles, R. H. & Wolfe, D. A. : Introduction to the theory of nonparametric statistics Hettmansperger, T. P. : Statistical Inference based on ranks Lehmann, E. L. : Theory of Point Estimation Shao, J. : Mathematical Statistics Fraser, D. A. S. : Nonparametric methods in Statistics Gibbons, J. D. : Nonparametric Inference Wald, A. : Sequential Analysis Mukhopadhyay, N. & de Silva, B. M. : Sequential Methods and their applications Gobindarajalu : Sequential Statistics

Semester	**SEVEN**
Paper	**Practical/Sessional Course - 9**
Paper Code	**STAT0791**
Paper Title	**Regression I**
No. of Credits	**4**

No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** General objectives of model building: inference and prediction, difference between parametric and non-parametric approaches. Review of simple linear regression and its properties (including sampling distributions), confidence interval for mean and prediction interval.
	Unit 2 Extension of linear regression: polynomial regression, multiple regression and general linear model, inference in linear model: general linear hypothesis and confidence intervals.
	Unit 3 Regression Diagnostics : Outlier detection, checking for heteroscedasticity and autocorrelation, multicollinearity, tests for normality of errors.
	Unit 4 Linear Smoothers and Non-parametric Regression Techniques: K-NN, Kernel Regression, Splines, Additive models.
Reading/ Reference Lists	Kutner, Nachtsheim, Neter: Applied Linear Regression Models Faraway, J.J.: Linear Models with R Berk, R.A.: Regression Analysis: A Constructive Critique James G,Witten D,Hastie T,Tibshirani R: Introduction to Statistical Learning with Applications in R Hastie,T, Tibshirani R.,Friedman J: Elements of Statistical Learning. Draper,N.R. and Smith,H.:Applied_Regression Analysis. Johnston,J. and DiNardo,J.: Econometric Methods Weisberg, S. :Applied linear regression. Györfi, László, et. al.: A Distribution-Free Theory of Nonparametric Regression. Simonoff, Jeffrey S. : Smoothing Methods in Statistics.

Semester	**SEVEN**
Paper	**Practical/Sessional Course - 10**
Paper Code	**STAT0792**
Paper Title	**Statistical Computing**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** Review of basic data structures, basic plotting techniques and writing functions in R. Basic Statistical methodologies in R. Reading and writing non-R formats, Handling Text and Image data in R, 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. Advanced plotting using ggplot.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.
	Unit 2 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. Introduction to Parallel computing in R.
	Unit 3 Review of concept of Simulation, Different methods of generation of random samples, Monte-Carlo techniques and applications. Mixture models and EM algorithm. Handling missing data.
	Unit 4 Simple optimization: Basics from calculus about minima, Taylor series. Gradient descent and Newton's method. Curve-fitting by optimization. Illustrations with optim and nls. Nelder-Mead and coordinate descent method with applications. Optimization under constraints, using Lagrange multipliers to turn constrained problems into unconstrained ones, Barrier methods for inequality constraints, The correspondence between constrained and penalized optimization, Statistical uses of penalized optimization in regression, Karush–Kuhn–Tucker conditions (concepts only). Stochastic optimization: stochastic gradient descent.
Reading/ Reference Lists	Teetor, P.: The R Cookbook. Chang, W.: The R Graphics Cookbook Spector, P: Data Manipulation with R. Burns, P.: The R Inferno. Matloff, N.: The Art of R Programming: A Tour of Statistical Software Design Ross, S. : Simulation Grolemund, G. and Wickham, H.: R for Data Science. Vandenberghe, L. and Boyd, S.P. : Convex Optimization. Rubin D. and Little, R.J.A. : Statistical Analysis with Missing Data. Xie, Y.: Dynamic Documents with R and knitr

Semester	**EIGHT**
Paper	**Practical/Sessional Course - 11**
Paper Code	**STAT0891**
Paper Title	**Regression II**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** Generalized linear models: Components of a GLM, Goodness of fit – deviance, Residuals, Maximum likelihood estimation. Binary data and Count data: ungrouped and grouped. Polytomous data Overdispersion, Quasi-likelihood. Models with constant coefficient of variation, joint modeling of mean and variance.
	Unit 2 Supervised learning and its decision theoretic formulation, Regression as a supervised learning method, in sample error, and extra sample error, different approaches of model selection : Adjusted R2, AIC, Mallow's Cp, Splitting the dataset, Cross-validation. Bias and Variance Tradeoff.
	Unit 3 High dimensional Regression techniques: Variable selection methods : Best Subset selection, Forward Selection, Backward selection. Shrinkage methods : Ridge Regression,

	Lasso and generalizations. Methods of derived input : Principal Component Regression and Partial Least Squares.
	Unit 4 Regression tree.
Reading/ Reference Lists	McCullagh, P and Nelder, A.J. : Generalized Linear Models. James G, Witten D, Hastie T,Tibshirani R : Introduction to Statistical Learning with Applications in R Hastie,T, Tibshirani R., Friedman J: Elements of Statistical Learning. Faraway, J.J.: Extending the Linear Model with R Breiman, Leo et. al. : Classification and Regression Trees. Agresti, A.: Categorical Data Analysis.

Semester	**EIGHT**
Paper	**Practical/Sessional Course - 12**
Paper Code	**STAT0892**
Paper Title	**Sample Survey and Design of Experiments**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** Probability sampling from a finite population – notions of sampling design, sampling scheme, inclusion probabilities, Horvitz-Thompson estimator of a population total, basic sampling schemes, unequal probability sampling with and without replacement, systematic sampling,related estimators of population total/mean, their variances and variance estimators – mean per distinct unit in simple random with replacement sampling. Hansen-Hurwitz estimator in unequal probability sampling with replacement. Des Raj and Murthy's estimator (for sample of size two) in unequal probability sampling without replacement, unbiased ratio estimators – probability proportional to aggregate size sampling, Hartley-Ross estimator in simple random sampling.
	Unit 2 Sampling and sub-sampling of clusters. Two-stage sampling with unequal number of second stage units and simple random sampling without replacement/unequal probability sampling with replacement at first stage, ratio estimation in two-stage sampling. Double sampling for stratification. Double sampling ratio and regression estimators. Sampling on successive occasions. Introduction to small area estimation.
	Unit 3 Block designs : connectedness, orthogonality, variance balance, construction of mutually orthogonal latin squares (MOLS).
	Unit 4 BIB designs – properties, Intra-block analysis, construction through mols, Bose's difference method and block section and intersection, resolvable BIB designs, factorial designs : analysis, confounding and balancing in symmetric factorials (prime-power case). Brief idea of response surface methodology.
Reading/	Cochran, W. G. : Sampling Techniques (1977)

Reference Lists	Raj, D. & Chandhok, P. : Sample Survey Theory Murthy, M. N. : Sampling : Theory and Methods (1968) Chaudhuri, A. : Modern Survey Sampling (2014) Chaudhuri, A. : Randomized Response and Indirect Questioning in Surveys (2011) Chakraborty, M. C. : Mathematics of Design and Analysis of Experiments Dey, A. : Theory of Block Designs Raghavarao, D. : Constructions & Combinatorial Problems in Designs of Experiments Bose, R. C. : Mathematical Theory of Symmetric Factorial Design (Sankhya – Vol. 8) Bose, R. C. : On the Construction of Balanced Incomplete Block Design (Annals of Eugenics – Vol. 9) Bose, R. C. : On Application of Galois fields to the problem of construction of hyper-graeco-latin square -Sankhya Vol.3, page 328 – 338 Montogomery, D. C. : Design and Analysis of Experiments

Semester	**NINE**
Paper	**Practical/Sessional Course - 13**
Paper Code	**STAT0991**
Paper Title	**Analysis of Time Series and Spatial Data**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** Illustration and recap of time series data and summary statistics like trend, seasonal index, classical decomposition, correlogram. Weakly and strongly stationary stochastic process on time and their interrelationships, Gaussian process on time. WN, MA, AR and ARMA process, existence and uniqueness of stationary solution, causality, invertibility, solution of recurrence relation for finding their ACVF and ACF.
	Unit 2 Estimation in MA, AR and ARMA model, Yule-Walker, MOM and conditional least squares approach, PACF and order selection of MA, AR and ARMA process. Forecasting – Simple Exponential Smoothing, Holt's and Holt-Winters' method. Box-Jenkins approach, ARIMA models. Projection approach for optimal prediction/forecast. Forecast interval and density forecasting. Unit root test for detection of stationarity.
	Unit 3 Frequency domain analysis, Bochner's theorem, Herglotz's theorem, spectral distribution and density of different processes. Estimation in frequency domain, periodogram analysis, inconsistency of periodogram estimator and its remedy using smoothing window estimators.
	Unit 4 Introduction to spatial data – some examples, classifications. Graphical display and summary statistics associated with point-referenced, lattice and spatial point process data, variogram analysis. Modeling of point-referenced sptial data and different methods of kriging.
Reading/ Reference Lists	C.Chatfield : The Analysis of Time Series – An Introduction Brockwell, Peter J. & Davis, Richard A. : Time Series - Theory and Methods G.E.P.Box ,G.M.Jenkins & G.C.Reinsel : Time Series Analysis – Forecasting and Control A.Pankratz : Forecasting with Univariate Box-Jenkins Model G. Jancek and L. Swift : Time Series – Forecasting, Simulation, Applications

	Robert H. Shumway & David S. Stoffer : Time Series Analysis and Its Applications B Ripley : Spatial Statistics N. Cressie : Statistics for Spatial Data N. Cressie & C. Wikle : Statistics for Spatio-temporal Data Sudipto Banerjee, B. P. Carlin & A. E. Gelfand : Hierarchical Modeling and Analysis for Spatial Data

Semester	**NINE**
Paper	**Practical/Sessional Course - 14**
Paper Code	**STAT0992**
Paper Title	**Applied Multivariate Analysis and Resampling**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** Introduction to multivariate data and potential applications. Curse of dimensionality and need for dimension reduction. Population and sample principal component and their uses. Canonical variables and canonical correlations and their interpretations. The orthogonal factor model, estimation of factor loading and factor scores. Multidimensional scaling. MANOVA.
	Unit 2 Difference between supervised and unsupervised learning. Hierarchical clustering for continuous and categorical variables, use of different proximity measures, non-hierarchical clustering methods : k-means clustering and related methods.
	Unit 3 Classification and discrimination procedures for discrimination between populations, classification using linear and logistic regression and nearest neighbor approach. Decision theoretic formulation: Bayes, minimax and likelihood ratio procedures, discrimination between two multivariate normal populations and linear discriminant analysis. Fisher's LDF. Classification tree.
	Unit 4 Introduction to the Jackknife, bias reduction using Jackknife, Jackknife bias estimate of standard statistics, Tukey's Jackknife variance estimate, introduction to deleted jackknife. Introduction to the bootstrap method, bootstrap sampling distribution of a statistic, bootstrap in regression models, bootstrap consistency measures.
Reading/ Reference Lists	R. A. Johnson & D. W. Wichern : Applied Multivariate Statistical Analysis. Léopold Simar & Wolfgang Härdle : Applied Multivariate Statistical Analysis. K. V. Mardia, J. T. Kent, J. M. Bibby : Multivariate Analysis T.W. Anderson : An Introduction to Multivariate Analysis. G.A.F. Seber : Multivariate Observations. B.Efron : The Jackknife, the Bootstrap and other Sampling Plans B.Efron : Bootstrap methods – another look at jackknife B.Efron & R.J.Tibshirani : An Introduction to the Bootstrap A. C. Davison & D. V. Hinkley : Bootstrap Methods and Their Application

Semester	**TEN**
Paper	**Practical/Sessional Course - 15**
Paper Code	**STAT1091**
Paper Title	**Combined Lab for STAT1001, STAT1002 and STAT1003**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1**
	Unit 2
	Unit 3
	Unit 4
Reading/ Reference Lists	

Semester	**TEN**
Paper	**Practical/Sessional Course - 16**
Paper Code	**STAT1092**
Paper Title	**Project**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1**
	Unit 2
	Unit 3
	Unit 4
Reading/ Reference Lists	