KANNUR UNIVERSITY

(Abstract)

M.Sc. Statistics Programme (CBCSS) in the university Department - Elective & Open Elective Courses - Scheme & Syllabus modified - implemented w.e.f. 2021 Admission - Orders issued.

ACADEMIC C SECTION

ACAD/ACAD C4/12980/2020 Dated: 07.12.2022

Read:-1. U.O. No. Acad/C4/12980/2020 dated 29.03.2021

2. Letter No. ACAD C/ACAD C3/4236/2021(1) dated 27.09.2022

3. The Minutes of the meeting of the Department Council, Dept of Statistical Sciences dated 10.10.2022

4. Syllabus submitted by the HoD, Dept of Statistical Sciences dated 05.12.2022

ORDER

1. As per paper read (1) above, the Scheme, Syllabus and Model question papers of M.Sc. Statistics Programme (CBCSS) revised and implemented in the University Department - w.e.f 2020 admission .

2. As per paper read (3) above, the Department Council, Department of Statistical Sciences resolved to incorporate the following modifications in the Syllabus for implementation w e f 2021 admission onwards as requested, as per paper read (2) above.

-To shift the following Open Elective Courses from fourth semester to third semester

1.MSSTA03O01 - Statistical Methods Using R and SPSS
2.MSSTA03O02- Stochastic Processes
3.MSSTA03O03- Applied Regression Analysis
4. MSSTA03O04 - Bayesian Computing with R
5.MSSTA03O05 - Mixture Regression Models
6.MSSTA03O06 - Statistical Quality Control

-To shift the Elective Course- MSSTA04E10 - Lifetime Data Analysis from third semester to fourth semester

-To shift the Elective Course- MSSTA03E04- Reliability Modeling from fourth semester to third semester

3. As per paper read (4) above, HoD, Dept. of Statistical Sciences submitted the modified Scheme, Syllabus of M.Sc. Statistics Programme (CBCSS) for implementation with effect from 2021 admission.

4. The Vice Chancellor after considering the matter in detail and in exercise of the powers of the Academic Council conferred under section 11 (1) Chapter III of Kannur University Act 1996 accorded sanction to implement the modified Scheme and Syllabus of M.Sc. Statistics Programme (CBCSS) in the Department of Statistical Sciences, Mangattuparamba Campus, as detailed in para (2) above, with effect from 2021 admission, and to report to the Academic Council.

5.The modified Scheme & Syllabus of M.Sc. Statistics Programme (CBCSS) implemented with effect from 2021 admission are appended and uploaded in the University Website.**(www.kannuruniversity.ac.in**).

6.The UO read (1) above stand modified to this effect

Orders are issued accordingly.

Sd/-
BALACHANDRAN V K
DEPUTY REGISTRAR (ACAD)
For REGISTRAR

To: 1. The Head, Dept. Statistical Sciences
Mangattuparamba Campus, Kannur

Copy To: 1. The Examination Branch (through PA to CE).
2. PS to VC / PA to PVC / PA to R
3. DR / AR 1/ AR II (Acad), EXCI, EPIV
4. The Web Manager (for uploading in the Website), Computer Programmer
5. SF / DF /FC

Forwarded / By Order
SECTION OFFICER

SECTION OFFICER

KANNUR UNIVERSITY

DEPARTMENT OF STATISTICAL SCIENCES
Choice Based Credit Semester System (CBCSS)

M.Sc. STATISTICS SYLLABUS
(Effective from 2021 Admission)

CONTENTS

1. ABOUT THE DEPARTMENT

The Department of Statistical Sciences which was established in 2008 at Mangattuparamba Campus, Kannur has the highest objective of producing a team of young statisticians from the jurisdiction of Kannur. To this purpose, the department is currently offering Postgraduate (M.Sc.) and Doctoral (Ph.D.) programmes in Statistics. The Department has an internet enabled computer lab with licensed SPSS software. The Department imparts rigorous training and exposure to the students in computer education by way of introducing the latest state-of-the-art in the programming language and computer software to enable to the students to perform statistical data analysis. There is a good collection of books in the department with latest titles in various areas of statistics.

2. INTRODUCTION TO CHOICE BASED CREDIT SYSTEM (CBCS)

The CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill-based courses. The courses can be evaluated following the grading system, which is considered to be better than the conventional marks system. Grading system provides uniformity in the evaluation and computation of the Cumulative Grade Point Average (CGPA) based on student's performance in examinations which enables the student to move across institutions of higher learning. The uniformity in evaluation system also enable the potential employers in assessing the performance of the candidates.

2.1. DEFINITIONS:

(i) **Academic Programme** means an entire course of study comprising its programme structure, course details, evaluation schemes etc. designed to be taught and evaluated in a teaching Department/Centre or jointly under more than one such Department/ Centre.

(ii) **Course** means a segment of a subject that is part of an Academic Programme.

(iii) **Programme Structure** means a list of courses (Core, Elective, Open Elective) that makes up an Academic Programme, specifying the syllabus, Credits, hours of teaching, evaluation and examination schemes, minimum number of credits required for successful completion of the programme etc. prepared in conformity to University Rules, eligibility criteria for admission.

(iv) **Core Course** means a course that a student admitted to a particular programme must successfully complete to receive the degree and which cannot be substituted by any other course.

(v) **Elective Course** means an optional course to be selected by a student out of such courses offered in the same or any other Department/Centre.

(vi) **Open Elective** means an elective course which is available for students of all other programmes . Students of other Department will opt these courses subject to fulfilling of eligibility of criteria as laid down by the Department offering the course.

(vii) **Credit** means the value assigned to a course which indicates the level of instruction; One-hour lecture per week equals 1 Credit, 2 hours practical class per week equals 1 credit. Credit for a practical could be proposed as part of a course or as a separate practical course.

(viii) **SGPA** means Semester Grade Point Average calculated for individual semester.

(ix) **CGPA** is Cumulative Grade Points Average calculated for all courses completed by the students in the last year of the course by clubbing together SGPA of four semesters.

2.2. PROGRAMME EDUCATIONAL OBJECTIVES:

PEO - 1: To teach theoretical aspects of various statistical methods and its application.

PEO - 2: To train students to handle large data sets and carry out data analysis using software and programming language.

PEO - 3: To inculcate and develop aptitude to apply statistical tools at a number of data generating fields in real life problems.

PEO - 4: To equip the students to undertake project work and communicate effectively

PEO -5: To train and prepare the students so as to enable them to take prominent roles in a wide spectrum of employment and research.

2.3. PROGRAMME OUTCOMES:

On successful completion of the programme a student will be able to:

PO-1: Gain sound knowledge in theoretical and practical aspects of Statistics.

PO-2: Acquire the working knowledge of various statistical software and programming language

PO-3: Acquire skills and competencies in statistical computing methods and develop algorithms and computer programmes for analyzing complex data sets

PO-4: Communicate effectively complex statistical ideas to people working in diverse spheres of academics and organizational set ups.

PO-5: Handle and analyze large databases and make meaningful interpretations of the results.

PO-6: Get wide range of job opportunities in industry as well as in government sector.

PO-7: Make unique contribution for the development of discipline by addressing complex and challenging problems in emerging areas of the discipline.

PO-8: Imbibe effective scientific and/or technical communication in both oral and writing.

PO-9: Continue to acquire relevant knowledge and skills appropriate to professional activities and demonstrate highest standards of ethical issues in statistical sciences.

PO-10: Create awareness to become an enlightened citizen with commitment to deliver one's responsibilities within the scope of bestowed rights and privileges.

2.4. PEO-PO MAPPING

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8	PSO-9	PSO-10
PEO-1										
PEO-2										
PEO-3										
PEO-4										
PEO-5										

3. M.SC. STATISTICS PROGRAMME DETAILS

M.Sc. Statistics programme is a two-year programme divided into four semesters. A student is required to complete 80 credits for the completion of programme and the award of degree.

3.1. PROGRAMME STRUCTURE

		Semester	Semester
Part-I	First Year	Semester I	Semester II
Part-II	Second Year	Semester III	Semester IV

COURSE CREDIT SCHEME:

Semester	Core courses		Elective Courses		Open Courses		TotalCredits
	No. of Papers	Total Credits	No. of Papers	Total Credits	No. of Papers	Total Credits	
I	**5**	**19**	**0**	**0**	**0**	**0**	**19**
II	**5**	**19**	**0**	**0**	**0**	**0**	**19**
III	**3**	**10**	**2**	**8**	**1**	**4**	**22**
IV	**1**	**8**	**3**	**12**	**0**	**0**	**20**
Total	**14**	**56**	**5**	**20**	**1**	**4**	**80**

SEMESTER WISE DETAILS:

SEMESTER -I						
Number of Core Courses: 5						
Sl.No	Course Code	Course Title	Theory	Practical	Tutorial	Credits
1	MSSTA01C01	Measure and Probability	4	0	0	4
2	MSSTA01C02	Mathematical Methods for Statistics	4	0	0	4
3	MSSTA01C03	Distribution Theory	4	0	0	4
4	MSSTA01C04	Sampling Theory	4	0	0	4
5	MSSTA01P01	Statistical Computing -I **(Practical)**	0	3	0	3
	Total credit in core courses		16	3	0	**19**
	Number of elective courses: 0					
	Credits in each course		Theory	Practical	Tutorial	Credits
	Total credits in elective courses		0	0	0	0
	Number of open elective courses: 0					
	Total credits in open elective courses		0	0	0	0
	Total credits in Semester –I		16	3	0	**19**

SEMESTER –II						
Number of Core Courses: 5						
Sl.No	Course Code	Course Title	Theory	Practical	Tutorial	Credits
1	MSSTA02C01	Advanced Probability Theory	4	0	0	4
2	MSSTA02C02	Stochastic Processes	4	0	0	4
3	MSSTA02C03	Estimation Theory	4	0	0	4
4	MSSTA02C04	Testing of Hypotheses	4	0	0	4
5	MSSTA02P01	Statistical Computing -II **(Practical)**	0	3	0	3
	Total credit in core courses		16	3	0	**19**
	Number of elective courses: 0					
	Credits in each course		Theory	Practical	Tutorial	Credits
	Total credits in elective courses		0	0	0	0
	Number of open elective courses: 0					
	Total credits in open elective courses		0	0	0	0
	Total credits in Semester –II		16	3	0	**19**

SEMESTER –III						
Number of Core Courses: 3						
Sl.No	Course Code	Course Title	Theory	Practical	Tutorial	Credits
1	MSSTA03C01	Multivariate Analysis	4	0	0	4
2	MSSTA03C02	Design and Analysis of Experiments	4	0	0	4
3	MSSTA03P01	Statistical Computing -III **(Practical)**	0	2	0	2
	Total credit in core courses		8	2	0	**10**
	Number of elective courses: 2					
Credits in each course			Theory	Practical	Tutorial	Credits
MSSTA03E01 /02/03/04/05	Elective Course 1		4	0	0	4
MSSTA03E01 /02/03/04/05	Elective Course II		4	0	0	4
Total credits in elective courses			8	0	0	**8**
Number of open elective courses: 1						
Open elective courses						4*
Total credits in Semester –III			16	2	0	**18+4=22**

SEMESTER -IV						
Number of Core Courses: 1						
Sl.No	Course Code	Course Title	Theory	Practical	Tutorial	Credits
1	MSSTA04C01	Dissertation	0	0	8	8
	Total credit in core courses		0	0	8	8
	Number of elective courses: 3					
Credits in each course			Theory	Practical	Tutorial	Credits
MSSTA04E06/07/08 /09/10/11/12	Elective Course 1		4	0	0	4
MSSTA04E06/07 /08/09/10/12	Elective Course 2		4	0	0	4
MSSTA04P01	Statistical Computing -IV **(Practical)**		0	4	0	4
Total credits in elective courses			8	4	0	12
Number of open elective courses: 0						
Total credits in Semester –IV			8	4	8	**20=20**

Selection of Elective Courses:

For selection of elective courses, a student may choose one course in semester III and two courses in semester IV from the lists of options being offered by the Department.

LIST OF ELECTIVECOURSES			
CODE	COURSE TITLE	L-T-P	Total Credit
MSSTA03E01	Analysis of Clinical Trials	4-0-0	4
MSSTA03E02	Analysis of Longitudinal Data	4-0-0	4
MSSTA03E02	Applied Regression Analysis	4-0-0	4
MSSTA03E04	Reliability Modeling	4-0-0	4
MSSTA03E05	Operations Research	4-0-0	4
MSSTA04E06	Advanced Distribution Theory	4-0-0	4
MSSTA04E07	Advanced Bayesian Computing with R	4-0-0	4
MSSTA04E08	Mixture Regression Models	4-0-0	4
MSSTA04E09	Queueing Theory	4-0-0	4
MSSTA04E10	Lifetime Data Analysis	4-0-0	4
MSSTA04E11	Statistical Quality Control	4-0-0	4
MSSTA04E12	Time Series Analysis	4-0-0	4

Open Elective Courses:

Open elective courses mean an elective course which are available for students of all other programmes in the University. Students of other Departments may opt these courses subject to fulfilling of eligibility criteria as laid down by the Department offering the course. Students can join for the open course depending on their choice and availability of seats in the departments offering such courses.Open Courses can be opted in the third Semesters.

Teaching:

The faculty of the Department is primarily responsible for organizing lecture work of M.Sc. Statistics. There shall be 90 instructional days excluding examination in a semester.

3.2. ELIGIBILITY FOR ADMISSIONS:

Candidates who have studied B.Sc. Statistics with minimum of 50% marks or equivalent grade in core course or B.Sc. Mathematics with Statistics as complementary course with 50% marks or equivalent grade in complementary (Statistics) course. The minimum requirement for admission to a Post Graduate Program shall be Grade C or overall CGPA 1.5 under CCSS /Grade C+ or CGPA 2 in Part III under grading system subject to satisfying other eligibility criteria prescribed for post graduate program of the Kannur University.

RELAXATION & WEIGHTAGE:

Usual relaxation of marks or GPA shall be given to eligible categories as per the following rules.

1. SC/ST Category: minimum pass marks in the relevant subjects or part of subjects is required for admission to PG Degree program.
2. OBC Category: a relaxation of 5% of marks in the concerned subjects or part of subjects from the prescribed minimum is allowed.
3. OEC Category: a relaxation of 5% of marks in the qualifying examination from the prescribed minimum is allowed.

NUMBER OF SEATS -25

MODE OF SELECTION:

The selection will be based on the marks obtained in the Entrance test to be conducted by the Kannur University.

3.3. ASSESSMENT OF STUDENTS PERFORMANCE AND SCHEME OF EXAMINATIONS

ATTENDANCE

The minimum attendance required for each Course shall be 60% of the total number of classes conducted for that semester. Those who secure the minimum attendance in a semester alone will be allowed to register for the End Semester Examination. Condonation of attendance to a maximum of 10 days in a Semester subject to a maximum of two spells within a Programme will be granted by the Vice-Chancellor. Benefit of Condonation of attendance will be granted to the students on health grounds, for participating in University Union activities, meetings of the University Bodies and participation in extra-curricular activities on production of genuine supporting documents with the recommendation of the Head of the Department concerned. A student who is not eligible for Condonation shall repeat the Course along with the subsequent batch.

EVALUATION

There shall be two modes of evaluation - the Continuous Evaluation (CE) and the End Semester Evaluation (ESE). The total mark for each course including the Project shall be divided into 40% for CE and 60% for ESE. Continuous Evaluation includes Assignments, Seminars, periodic written examinations etc. The component wise division of the 40% CE mark are as follows.

Theory		Practical	
Components	% of marks	Components	% of marks
Test papers	40% (16 marks)	Tests	75% (30 marks)
Tutorial with viva, Seminar presentations, Discussion, Debate etc.	40% (16 marks)	Record	25%(10 marks)
Assignment	20% (8 marks)		
Total Internal marks	40	Total internal marks	40

The ESE shall be made based on examinations for each course conducted by Controller of Examinations. as per the common norms under the CCSS. The question paper for ESE for Theory Examinations shall contain three sections. The Question paper should contain minimum 3 questions from each unit and should not contain more than 5 questions from the same unit. The distribution of the no of questions and marks are given in the following table.

Part	Marks	Number of questions to be answered	Number of questions in the question paper	Type of questions (Level - Bloom's Taxonomy)
A	15	5	6	1 Remembering 2 Understanding
B	15	3	5	6. creating
C	30	3	5	3. Applying 4. Analysing 5. Evaluating
Total	60	11	16	

PRACTICAL

Practical is to be done using R programme/ SPSS software. Practical Record shall be maintained by each student and the same shall be submitted for verification at the time of external examination. Students are expected to acquire working knowledge of the statistical software R and SPSS. The Board of Examiners (BoE) shall decide the pattern of question paper and the duration of the external examination. The external examination at the centre shall be conducted and evaluated on the same day jointly by two examiners – one external and one internal. The question paper for the external examination at the centre will be set by the external examiner in consultation with the head of the department of the centre. The questions are to be evenly distributed over the entire syllabus. Evaluation shall be done by assessing each candidate on the scientific and experimental skills, the efficiency of the algorithm/program implemented, the presentation and interpretation of the results.

DISSERTATION & SUBJECT VIVA

Project work has **8** credits. The duration of the project work is 3 months. Candidates can do the project work either based on real life data or can prepare a dissertation based on latest research articles published in reputed international Journals. The work can be done in the department itself or candidates can go to any reputed department/institution outside the campus, approved for doing research or advanced studies. The department/University may establish close link with such institutions for the purpose, by way of executing appropriate MoU if required.

There shall be a board of at least three examiners (At least one external expert) for the evaluation of the project work. Each candidate has to submit a copy of the Project Report approved by the project guide before the last date fixed by the department. The candidate has to present the project before the board of examiners which will be followed by a Viva. The ESE for the project will be made jointly by the board of examiners based on the report, its presentation and Viva. The total ESE marks for Project /Dissertation work shall be 50.

A comprehensive viva based on all courses offered for the M.Sc. Program will be conducted at the end of all other examinations by the same board of examiners who conducted the Project Evaluation. The total ESE marks for Subject Viva shall be 10

SCHEME OF END SEMESTER EXAMINATIONS:

SEMESTER -I

Sl. No	Course Code	Title of the Course	Credits	Duration of Exam	Max. Marks
1	MSSTA01C01	Measure and Probability	4	3hrs	60
2	MSSTA01C02	Mathematical Methods for Statistics	4	3hrs	60
3	MSSTA01C03	Distribution Theory	4	3hrs	60
4	MSSTA01C04	Sampling Theory	4	3hrs	60
5	MSSTA01P01	Statistical Computing -I **(Practical)**	3	3hrs	60

SEMESTER -II

Sl. No	Course Code	Title of the Course	Credits	Duration of Exam	Max. Marks
1	MSSTA02C01	Advanced Probability Theory	4	3hrs	60
2	MSSTA02C02	Stochastic Process	4	3hrs	60
3	MSSTA02C03	Estimation Theory	4	3hrs	60
4	MSSTA02C04	Testing of Hypotheses	4	3hrs	60
5	MSSTA02P01	Statistical Computing -II **(Practical)**	3	3hrs	60

SEMESTER -III

Sl. No	Course Code	Title of the Course	Credits	Duration of Exam	Max. Marks
1	MSSTA03C01	Multivariate Analysis	4	3hrs	60
2	MSSTA03C02	Design and Analysis of Experiments	4	3hrs	60
3	MSSTA03E01/ 02/03/04/05	Elective - 1	4	3hrs	60
4	MSSTA03E01/ 02/03/04/05	Elective - 2	4	3hrs	60
5	MSSTA03P01	Statistical Computing -III **(Practical)**	2	3hrs	60
6		Open Elective	4	3hrs	60

SEMESTER -IV

Sl. No	Course Code	Title of the Course	Credits	Duration of Exam	Max. Marks
1	MSSTA04E06/07 /08/09/10/11/12	Elective- 3	4	3hrs	60
2	MSSTA04E06/07 /08/09/10/11/12	Elective- 4	4	3hrs	60
3	MSSTA04P01	Statistical Computing-IV **(Practical)**	4	3hrs	60
4	MSSTA04C01	Project/Dissertation Subject Viva	8		60

3.4 SPAN PERIOD

No students shall be admitted as a candidate for the examination for any of the Years/Semesters after the lapse of 4 years from the date of admission to the first year of the M.A./M.Sc. programme.

3.5 CONVERSION OF MARKS INTO GRADES

An alphabetical Grading System shall be adopted for the assessment of a student's performance in a Course. The grade is based on a 6-point scale. The following table gives the range of marks %, grade points and alphabetical grade.

Range of Marks%	Grade Points	Alphabetical Grade
90-100	9	A+
80-89	8	A
70-79	7	B+
60-69	6	B
50-59	5	C
Below 50	0	F

A minimum of grade point 5 (Grade C) is needed for the successful completion of a course. A student who has failed in a course can reappear for the end semester examination of the same course along with the next batch without taking re-admission or choose another course in the subsequent semesters of the same programme to acquire the minimum credits needed for the completion of the programme. There shall not be provision for improvement of CE and ESE.

3.6 GRADE POINT AVERAGE (GPA)

Performance of a student at the end of each Semester is indicated by the Grade Point Average (GPA) and is calculated by taking the weighted average of grade points of the Courses successfully completed. Following formula is used for the calculation. The average will be rounded off to two decimal places.

$$CGPA = \frac{\text{Sum of (grade points in a course multiplied by its credit)}}{\text{Sum of Credits of Courses}}$$

3.7 CGPA CALCULATION

At the end of the Programme, the overall performance of a student is indicated by the Cumulative Grade Point Average (CGPA) and is calculated using the same formula given above. Empirical formula for calculating the percentage of marks will be **(CGPA x 10) +5.** Based on the CGPA overall letter grade of the student and classification shall be in the following way.

CGPA	Overall Letter Grade	Classification
8.5 and above	A+	First Class with Distinction
7.5 and above but less than 8.5	A	
6.5 and above but less than 7.5	B+	First Class
5.5 and above but less than 6.5	B	
5 and above but less than 5.5	C	Second Class

Appearance for Continuous Evaluation (CE) and End Semester Evaluation (ESE) are compulsory and no Grade shall be awarded to a candidate if he/she is absent for CE/ESE or both.

A student who fails to complete the programme/semester can repeat the full programme/ semester once, if the department council permits to do so.

4. COURSE WISE CONTENT DETAILS FOR M.SC. STATISTICS PROGRAMME

4.1 THE DETAILED SYLLABUS - CORE COURSES

Objective of these courses are to impart the theoretical framework of different core areas of statistics to students.

Semester-I

MSSTA01C01 - MEASURE AND PROBABILITY

Course Objectives:	The main objective of this course is to introduce students the inter-link between measure and probability.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the concepts of measure and probability and properties. 2. Understand convergence of sequence of sets, sequence of measurable functions and sequence of integrals. 3. Understand convergence of sequence of random variables 4. Understand the inequalities involving moments

Unit-I. Measure and Measurable Function: Class of sets, limits of sequence of sets, fields and σ-fields, minimal σ-fields and Borel field, monotone class. Measurable space, measure, measure space, Lebesgue measure and counting measure, measurable functions and their properties. Limit of a sequence of measurable functions, simple functions, non-negative measurable functions as limit of simple functions.

Unit - II. Integral and Convergence of Sequence of Integrals: Integral of a simple function, integral of a measurable function. The monotone convergence theorem, Fatou's lemma. Bounded convergence theorem, Lebesgue dominated convergence theorem, normed linear spaces, Lp spaces, Holder's inequality, Minkowski's inequality.

Unit -III. Probability Measure and Random Variables: Axiomatic approach to probability, probability space, conditional probability space, independence of events and sigma fields, Bayes theorem. Real and vector valued random variables, distribution function, density function and properties, expectation of a random variable and properties. Sequence of random variables and different modes of convergence: in probability, in distribution, in r^{th} mean and almost sure, their mutual implications.

Unit IV: Expectation and Inequalities: Expectation of a function of random variable as Riemann - Stieltjes integral, moments of a random variable. Inequalities involving moments, Cr-inequality, Jenson's inequality, basic inequality, Markov equality and their applications.

Books for study

1. Bhat, B.R. (2004). *Modern Probability Theory*, New Age Publishers, New Delhi.

2. Robert G. Bartle (1995). *The Elements of Integration and Lebesgue Measure*. John Wiley & Sons, New York.

Reference books

1. Basu, A.K. (1999). *Measure Theory and Probability*, Prentice-Hall.

2. Billingsley, P.(1986). *Probability and Measure, Second Edition*, John Wiley.

3. Parthasarathy, K.R. (2005). *Introduction to Probability and Measure*, Hindustan Book Agency.

4. Royden, H. L. (1988). *Real Analysis, Third Edition,* Mc Millain Publishing Company, New-York.

MSSTA01C02-MATHEMATICAL METHODS FOR STATISTICS

Course Objectives:	The main objective of this course is to introduce the concepts of real analysis and matrix algebra and their applications in Statistics.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the concepts of limit and continuity of functions and their properties 2. Understand Reimann – Stieltjes integral and its properties. 3. Understand convergence of sequences and series of functions. 4. Understand the vector space, matrices and its properties 5. Understand the properties of quadratic forms and generalized inverses

Unit I. Limit and Continuity of Functions: Metric spaces, compact set, perfect set, connected set, limit of functions, continuous function, continuity and compactness, continuity and connectedness, discontinuities, monotone functions, derivative of a real valued function, mean value theorem. Reimann- Stieltjes integral and properties.

Unit-II. Sequence of Functions and Functions of Several variables: Sequences and series of functions, uniform convergence. Uniform convergence and continuity, uniform convergence and integration, uniform convergence and differentiation, Weirstrass theorem, improper integrals, the Beta and Gamma functions. Functions of several variables, limits and continuity. Taylor's theorem and its applications. Conditions for the optima of multivariate functions.

Unit III. Vector Spaces and Matrices: Vector space, sub spaces, linear dependence and independence, basis and dimensions, direct sum and compliment of a subspace, inner product and orthogonality. Algebra of matrices, linear transformations, different type of matrices. Row and column space of a matrix, inverse of a matrix, rank, factorization of a matrix, elementary operations and reduced forms.

Unit- IV. Spectral Decomposition and Quadratic Forms: Eigen values and eigen vectors, spectral representation and singular value composition, Cayley-Hamilton theorem, algebraic and geometric multiplicities, Jordan canonical form. Linear equations, generalized inverses and quadratic forms, rank nullity theorem, generalized inverses, Moore-Penrose inverse, computation of g-inverse. Quadratic forms, classification of quadratic forms, rank and signature, positive definite and non-negative definite matrices, simultaneous diagonalization of matrices.

Books for Study

1. Rudin. W. (2013). *Principles of Real Analysis (3rd Ed.),* McGraw Hill.
2. Ramachandra Rao and Bhimasankaran (1992). *Linear Algebra*. Tata McGraw Hill, New-Delhi.
3. Malik, S.C & Arora, S. (2006). *Mathematical Analysis*, *Second Edition,* New-age International Publishers.
4. Mathai, A. M. and Haubold, H. J. (2017). Linear Algebra – A course for Physicists and Engineers, De Gruyter, Germany.

Reference Books

1. Apsostol, T.M. (1974). *Mathematical Analysis*, *Second Edition*. Norosa, New Delhi.
2. Lewis, D.W. (1995). *Matrix theory*, Allied publishers, Bangalore.
3. Mathai, A. M. (1998). *Linear Algebra Part I, II & III.*, Centre for Mathematical Sciences.
4. Rao C.R. (2002). *Linear Statistical Inference and Its Applications*, *Second Edition*, John Wiley and Sons, New York.
5. Seymour Lipschupz, Marc Lipson (2005). *Schaum's Outline Series - Linear Algebra (3rd edition).* Tata McGraw Hill.

MSSTA01C03 - DISTRIBUTION THEORY

Course Objectives:	The aim of this course is to provide a thorough theoretical grounding in different type of statistical theoretical and sampling distributions.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the concepts of discrete and continuous distributions. 2. Understand the normal distribution and various non-normal distributions, their properties and applications for scientific research. 3. Understand the concept of multivariate distributions and their marginal and conditional distributions 4. Understand the idea of sampling and sampling distributions from infinite populations

Unit-1. Univariate Discrete Distributions: Moments and moment generating functions, probability generating functions, characteristic function. Discrete uniform, binomial, Poisson, geometric, negative binomial, hyper geometric and power series distributions.

Unit-2. Univariate Continuous Distributions: Uniform, normal, exponential, Weibull, Pareto, beta, Gamma, Laplace, logistic, Cauchy and log-normal distributions.

Unit-3. Bivariate and Multivariate Distributions: Joint, marginal and conditional distributions, independence, covariance and correlations, functions of random variables and their distributions. Jacobin of transformations, bivariate normal distribution, multinomial distribution and their marginal and conditional distributions.

Unit-4. Sampling Distributions: Basic concepts of sampling distributions from infinite populations, sampling from normal distributions, properties of sample mean and sample variance. Chi-square, t-distribution and F-distributions, properties and applications. Non-central Chi-square, t and F-distributions. Basic concepts of order statistics and their distributions. Distribution of rth order statistics, distribution of sample median and range (for Uniform (0,1) distribution only).

Books for study

1. Rohatgi, V.K. (2001). *An Introduction to Probability and Statistics*, 2^{nd} *Edition.* John Wiley and Sons.

2. Krishnamurthy, K. (2006). *Handbook of Statistical Distributions with Applications.* Chapman & Hall/CRC, New-York.

Reference books

1. Johnson, N.L., Kotz, S. and Balakrishnan, N. (1995). *Continuous Univariate Distributions, Vol. I & Vol. II,* John Wiley and Sons, New-York.

2. Johnson, N.L., Kotz. S. and Kemp. A.W. (1992). *Univarite Discrete Distributions,* John Wiley and Sons, New York.

3. Stuart, A. Ord, A. (1994). *Kendall's Advanced Theory of Statistics, Distribution Theory,6thEdition.* Wiley-Blackwell.

4. Gupta, S.C. and Kapoor, V.K. (2000). *Fundamentals of Mathematical Statistics, 10 th Revised Edition.* Sultan Chand & Sons, New Delhi

MSSTA01C04 - SAMPLING THEORY

Course Objectives:	The main objective of this course is to learn techniques in survey sampling with practical applications in empirical research.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the concepts of probability and non-probability sampling. 2. Understand the estimation methods for population mean, total and proportion under various sampling schemes. 3. Understand the use of auxiliary information for the estimation various population parameters

Unit-1. Simple Random Sampling and Systematic Random Sampling: Census and sampling-basic concepts, probability sampling and non-probability sampling, simple random sampling with and without replacement, estimation of population mean and total, estimation of sample size, estimation of proportions. Systematic sampling, linear and circular systematic sampling, estimation of mean and its variance, estimation of mean in populations with linear and periodic trends.

Unit-2. Stratified Random Sampling and Auxiliary Variable Techniques: Stratification and stratified random sampling. Optimum allocations, comparisons of variance under various allocations. Auxiliary variable techniques, Ratio method of estimation, estimation of ratio, mean and total. Bias and relative bias of ratio estimator. Mean squared error of ratio estimator. Unbiased ratio type estimator. Regression methods of estimation. Comparison of ratio and regression estimators with simple mean per unit method. Ratio and regression method of estimation in stratified population.

Unit-3. Varying Probability Sampling: Varying probability sampling – pps sampling with and without replacements. Des- Raj ordered estimators, Murthy's unordered estimator, Horwitz –Thompson estimators, Zen-Midzuno scheme of sampling, PPS sampling.

Unit -4. Cluster, Multi Stage and Multi-Phase Sampling: Cluster sampling with equal and unequal clusters. Estimation of mean and variance, relative efficiency, optimum cluster size, varying probability cluster sampling. Multi-stage and multiphase sampling. Non-sampling errors.

Books for Study

1. Singh, D and Chowdhary, F.S. (1986). *Theory and Analysis of Sample Survey Designs*, New Age International, NewDelhi.

2. Cochran.W.G. (2007). *Sampling Techniques*, John Wiley & Sons, NewYork

Reference books

1. Des Raj, D. and Chandhok, P.(1998). *Sample Survey Theory*, Narosa Publishing House, New Delhi.

2. Gupta and Kapoor (2010). *Fundamentals of Applied Statistics*. Sulthan Chand & Sons.

3. Murthy, M.N. (1967). *Sampling Theory & Methods*. Statistical Publishing Society, Calcutta.

4. Parimal Mukopadhyay (2012). *Theory & Methods of Survey Sampling*, PHI Learning, New Delhi.

Semester II

MSSTA02C01 - ADVANCED PROBABILITY THEORY

Course Objectives:	The aim of the course is to make a thorough knowledge about some fundamental theorems in probability such as continuity theorem on characteristic functions, laws of large numbers, central limit theorems and various decomposition theorems of signed measures with their applications.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the concepts of decomposition of measures. 2. Understand characteristic function and its properties 3. Understand various laws of large numbers 4. Understand different central limit theorems, their mutual implications and applications and the concept of conditional expectation and martingales.

Unit 1.Signed Measures and Decompositions: Signed measure space, singular and absolutely continuous measures, Radon-Nikodym theorem (without proof) and its applications. Decomposition of measures, Hahn Decomposition theorem, Hahn- Jordan decomposition, and Lebesgue decomposition theorem. Product space and product measure. Fubini's theorem (without proof).

Unit- 2. Characteristic Functions and Properties: Definition of a characteristic function, elementary properties, characteristic functions and moments, Taylor's series expansion of characteristic functions, Bochner's theorem (without proof), inversion theorem, uniqueness theorem, continuity theorem.

Unit -3. Law of Large Numbers and Independence of the class of events: The Weak laws of large numbers, the strong laws of large numbers and Kolmogorov three series theorem (withot proof), applications. Weak convergence of distributions. Helly's convergence theorem, Helly-Bray lemma, Scheffe theorem, Independence of class of events and random variables. Borel 0-1 criteria and Borel-Cantelli Lemma, Kolmogorov 0-1 laws.

Unit-4. Central Limit Theorems and Martingales: The central limit theorems – Lindberg Levy, Liapounov and Lindberg-Feller (without proof) central limit theorems, their mutual implications and applications. Conditional expectation, martingales, simple properties and examples.

Books for study

1. Bhat, B. R. (2004). *Modern Probability Theory*, New Age Publishers, New Delhi.
2. Laha, R. G. and Rohatgi, V.K. (2020). *Probability Theory*, Dover Publications Inc.
3. Robert G. Bartle (1995). *The Elements of Integration and Lebesgue Measure*, John Wiley & Sons, New York.

4. Rohatgi,V.K. (1976). *An Introduction to Probability Theory and Mathematical Statistics*, Wiley Eastern.

Reference books

1. Basu, A.K. (1999). *Measure Theory and Probability*, Prentice-Hall.

2. Billingsley, P.(1986). *Probability and Measure*, Second Edition, JohnWiley.

3. Parthasarathy, K.R. (2005). *Introduction to Probability and Measure*, Hindustan Book Agency.

4. Royden, H. L. (1988). *Real Analysis* (3rd edition), Mc Millain Publishing Company, New York.

MSSTA02C02 - STOCHASTIC PROCESSES

Course Objectives:	The main objective of this course is to develop awareness for the use of stochastic models for representing random phenomena evolving in time such as Poisson, Renewal, Branching, Queueing and Brownian motion process.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the concepts of Stochastic processes. 2. Understand the concepts of Markov chains, classification of its states and limiting probabilities. 3. Understand continuous time Markov chains, Poisson processes and its generalizations. 4. Understand the branching processes, various queueing models and Brownian motion process.

Unit 1. Basics Concepts of Stochastic Processes and Markov Chains: Concept of stochastic processes, examples, stationary and weakly stationary processes. Markov chains- Chapman Kolmogorov equations - classification of states - limiting probabilities; gamblers ruin problem and random walk, Branching processes (discrete time).

Unit- 2. Poisson Processes and Generalizations: Exponential distribution, counting process, inter arrival time and waiting time distributions. Properties of Poisson processes- Conditional distribution of arrival times. Generalizations of Poisson processes, non-homogenous Poisson process, compound Poisson process.

Unit -3.Continuous time Markov Chains and Renewal Processes: Continuous time Markov Chains- Birth and death processes, transition probability function, limiting probabilities. Renewal processes, limit theorems and their applications. Semi- Markov process.

Unit -4.Queueing and Brownian Motion Process: Basic characteristics of queues, analysis of Markovian models (M/M/1, M/M/1/N, M/M/c), network of queues. The M/G/I system and G/M/I model. Brownian motion process

Books for study

1. Ross, S. M. (2010). *Introduction to Probability Models. X th Edition*, Academic Press.

2. Medhi, J. (2009). *Stochastic Processes. Third Edition*. New Academic Science Limited. U K.

Reference books

1. Basu, A.K. (2002). *Elements of Stochastic Processes*, Narosa Publications.

2. Cinlar, E. (1975). *Introduction to Stochastic Processes*. Prentice Hall. New Jersey.

3. Feller, W. (1965, 1968), *An Introduction to Probability Theory and Its Applications, Volume I and II*, Wiley Eastern.

4. Karlin, S. and Taylor, H.M. (1975). *A First Course in Stochastic Processes*. *Second Edition*, Academic Press. New-York.

MSSTA02C03 - ESTIMATION THEORY

Course Objectives:	To make aware the students of parametric and Bayesian estimation (point, as well as interval) procedures.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Apply various parametric and Bayesian estimation techniques with real life examples. 2. Understand the concepts of Sufficiency and Completeness 3. Understand the concepts of Minimum Variance Unbiased Estimation. 4. Understand various estimation methods and applications in real life problems 5. Understand Bayesian inference methods and its application.

Unit 1. Sufficiency and Completeness: Sufficient statistics and minimum variance unbiased estimators, factorization theorem for sufficiency (proof for discrete distributions only), joint sufficient statistics, exponential family, minimal sufficient statistics, criteria to find the minimal sufficient statistics, ancillary statistics, complete statistics, Basu's theorem (proof for discrete distributions only).

Unit- 2. Minimum Variance Unbiased Estimation: Unbiased estimator, Best Linear Unbiased Estimator (BLUE), Minimum Variance Unbiased Estimator (MVUE), Fisher information, Cramer-Rao inequality and its applications, Rao-Blackwell theorem, Lehmann - Scheffe theorem. Consistent estimators and consistent asymptotically normal estimators. Invariance property of estimators and consistent asymptotically normal (CAN) estimators.

Unit -3.Methods of Estimation: Method of moments, Method of maximum likelihood (MLE), MLE in exponential family, one parameter Cramer family, Cramer- Huzurbazar theorem. Interval estimation, shortest expected length confidence interval, large sample confidence intervals.

Unit -4. Bayesian Inference: Randomized and non-randomized decision rules, risk and loss function, optimality of decision rules, standard loss functions prior and posterior distributions, estimation, confidence interval and prediction under Bayesian approach.

Books for study

1. Kale,B.K.(2005). *A First Course in Parametric Inference*, *Second Edition,* Narosa Publishing House, New Delhi.

2. Vijay K. Rohatgi, A. K. Md. Ehsanes Saleh (2015). *An Introduction to Probability and Statistics, 3rd Edition,* **John** Wiley and Sons, New York**.**

Reference Books

1. Casella, G. and Berger, R.L. (2002). *Statistical Inference*, *Second Edition,* Duxbury, Australia.

2. Bensal, A. K. (2008). *Bayesian Parametric Inference*, New Age, Delhi.

3. Lehmann, E.L (1983). *Theory of Point Estimation*, John Wiley and Sons, New York.

4. Rohatgi, V.K (2003). *Statistical Inference*, Dover Publications.

5. Rao, C.R (2002). *Linear Statistical Inference and Its Applications*, *Second Edi- tion,* John Wiley and Sons, NewYork.

MSSTA02C04 - TESTING OF HYPOTHESES

Course Objectives:	To make aware the students of parametric, non-parametric and sequential testing (simple, as well as, composite hypotheses) procedures.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Apply various parametric, non-parametric and sequential testing procedures to deal with real life problems. 2. Understand Most Powerful Tests for testing simple null hypothesis and developing MP tests for different problems 3. Understand UMP tests and likelihood ratio tests for testing composite hypothesis and developing UMP and likelihood ratio tests for different problems 4. Understand various non-parametric tests used for different problems 5. Understand the Sequential Probability Ratio Test and developing SPRT for different situations.

Unit 1. Tests of Hypotheses and Most Powerful Tests: Tests of hypotheses and most powerful Tests – Simple versus simple hypothesis testing problem - Error probabilities, p-value and choice of level of significance - Most powerful tests – Neyman Pearson Lemma, generalized Neyman - Pearson lemma.

Unit- 2.UMP Tests and Similar Tests: MLR property, One-sided UMP tests, two sided UMP tests and UMP unbiased tests, α –similar tests and similar tests with Neyman structure. Principle of invariance in testing of hypotheses, locally most powerful tests. Likelihood ratio tests, asymptotic distribution of likelihood ratio.

Unit -3. Non-parametric Tests: Non-parametric Tests: Single sample tests - testing goodness of fit, chi-square tests- Kolmogorov - Smirnov test - sign test - Wilcoxon signed rank test. Two sample tests - the chi-square test for homogeneity - Kolmogorov Smirnov test; the median test - Mann- Whitney - Wilcoxon test - Test for independence, Kendall's tau, Spearman's rank correlation coefficient

Unit -4. Sequential Tests: Some fundamental ideas of sequential sampling - Sequential Probability Ratio Test (SPRT) - important properties, termination of SPRT - Operating Characteristic (OC) function and Average Sample Number (ASN) of SPRT - Developing SPRT for different problems.

Books for Study

1. Casella, G. and Berger, R. L. (2002): *Statistical Inference, Second Edition*, Duxbury, Australia.

2. Vijay K. Rohatgi, A. K. Md. Ehsanes Saleh (2015). *An Introduction to Probability and Statistics, 3rd Edition,* John Wiley and Sons, New York.

3. Wald, A. (2004): *Sequential Analysis,* Dover Publications.

Reference books

1. Fraser, D.A. S. (1957): *Non - parametric Methods in Statistics*, Wiley, New York.

2. Lehman, E.L. (1986): *Testing of Statistical Hypotheses*. John Wiley, New York.

3. Ferguson, T.S. (1967*): Mathematical Statistics: A Decision - Theoretic Approach.* Academic Press, New York.

4. Srivastava, M. and Srivstava, N. (2009): *Statistical Inference: Testing of Hypothesis, Eastern Economy Edition*, PHI Learning Pvt. Ltd., New Delhi.

Semester III

MSSTA03C01 - - MULTIVARIATE ANALYSIS

Course Objectives:	The main objective of this course is to introduce generalizations of important univariate statistical methods to the multivariate situations where we have to deal with the analysis of observations on several correlated random variables for a number of individuals.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the concept of joint distributions, conditional distributions, marginal distributions and statistical independence. 2. Summarize and interpret multivariate data and understand the link between multivariate techniques and corresponding univariate techniques. 3. Understand Multivariate Normal Distribution its properties , parameter estimation methods and distribution of quadratic form of a multivariate random vector 4. Understand Hypothesis Tests based on Multivariate Normal Distribution with real data applications 5. Understand Classification Problem , Principal Component Analysis and Factor Analysis with real data applications

Unit 1. Multivariate Normal Distribution: Multivariate Normal Distribution –Definition and properties, conditional distributions, marginal distributions. Independence of a linear form and quadratic form, independence of two quadratic forms, distribution of quadratic form of a multivariate vector, partial and multiple correlation coefficients, partial and multiple regression coefficients.

Unit- 2. Estimation of Multivariate Normal Distribution and Wishart Distribution:
Estimation of mean vector and dispersion matrix - Maximum likelihood estimation of the mean vector and dispersion matrix. Distribution of simple, partial and multiple (null-case only) correlation coefficients; canonical correlation. Wishart distribution - properties – generalized variance.

Unit-3. Hypothesis Tests based on Multivariate Normal Distribution: Testing problems based on Mahalanobis D^2 and Hotelling's T^2 statistics, Likelihood ratio tests –Testing the equality of mean vector, equality of dispersion matrices, testing the independence of sub vectors, sphericity test.

Unit -4. Classification Problem and Principal Component Analysis: The problem of classification - classification of one of two multivariate normal populations when the parameters are known and unknown and extension to several multivariate normal populations. Population principal components - summarizing sample variation by principal components - iterative procedure to calculate sample principal components, factor analysis.

Books for Study

1. Anderson, T.W. (1984): *Multivariate Analysis.* John - Wiley, New York.

2. Rao, C.R. (2002): *Linear Statistical Inference and Its Applications, Second Edition,* John Wiley and Sons, New York.

Reference Books

1. Johnson, R. A. and Wichern, D.W. (2001): *Applied Multivariate Statistical Analysis, 3rd Edn.,* Prentice Hall of India, New Delhi.
2. Kshirasagar, A.M. (1972): *Multivariate Analysis*. Marcel Dekker, New-York

3. Rencher, A.C. (1998): *Multivariate Statistical Analysis*. Jon Wiley, New York.

4. Morrison, D.F. (1976): *Multivariate Statistical Methods*, McGraw Hill, New York.

MSSTA03C02 - DESIGN AND ANALYSIS OF EXPERIMENTS

Course Objectives:	This course provides the students the ability to understand the design and conduct experiments, as well as to analyze and interpret data.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Apply ANOVA for one way and two-way classification, fixed effect models with equal and unequal number of observations per cell, Random and Mixed effect models. 2. Design and analyse incomplete block designs, understand the concepts of orthogonality, connectedness and balance. 3. Identify the effects of different factors and their interactions and analyse factorial experiments. 4. Construct complete and partially confounded factorial designs and perform their analysis. 5. Apply Split-plot designs and their analysis in practical situations.

Unit1.Linear Models: Linear model, estimable functions and best estimate, normal equations, distribution of sum of squares, estimate and error sum of squares, test of linear hypothesis, basic principles and planning of experiments. The fixed, random and mixed models. The single and two factor ANOVA. Non-parametric method in analysis of variance, Kruskell-Wallis test.

Unit-2. Complete Block Designs: Complete Block Designs- Completely Randomized Design, Randomized Block Design, Latin Square Design, Greaco Latin Square Design, Analysis with Missing Values, ANCOVA.

Unit -3. Incomplete Block Designs: Incomplete Block Designs-BIBD, recovering of Intra Block Information in BIBD, construction of BIBD, PBIBD, Youden square, Lattice Design.

Unit -4. Factorial Designs: Factorial designs-basic definitions and principles, two factor factorial design – general factorial design, 2^k factorial design- Confounding and Partial Confounding, 3^2- factorial, asymmetric factorial, two level fractional factorial, Split Plot Design.

Books for Study

1. Das, M.N. and Giri, N.S. (2002): *Design and Analysis of Experiments, 2nd Edition*, New Age International (P) Ltd., New Delhi.

2. Joshi, D.D. (1987): *Linear Estimation and Design of Experiments*. Wiley Eastern Ltd., New Delhi.

3. Montgomery, D.C. (2001*): Design and Analysis of Experiments. 5th Edition,* John Wiley & Sons-New York.

Reference Books

1. Gupta, S. C and Kapoor, V.K. (2010). *Fundamentals of Applied Statistics*. Sulthan Chand & Co, New Delhi

2. Dean, A. and Voss, A. (1999): *Design and Analysis of Experiments*. Springer Verlag, New York.

3. Box, G.E .P. Hunter, W. (2005*): Statistics for Experimental Design, Innovations and Discovery, Vol. II*, Wiley

4.2. THE DETAILED SYLLABUS OF PRACTICAL COURSES

Semester-I

MSSTA01P01 -STATISTICAL COMPUTING-I

Course Objectives:	The objective of this courses is to enhance the programming skills and working knowledge of available statistical software and programming languages.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand various built in functions in R programming for statistical data analysis. 2. Understand different functions in R programming for writing computer programmes and develop computer programmes for different problems 3. Understand the usage of menus in SPSS window for drawing various diagrams and computing descriptive statistics, the comparison of means, ANOVA, non-parametric tests, simple correlation and regression procedures and apply for real data sets.

Unit 1. Basic Concepts of R Programming: Introduction to R- Objects and their classes, operators, vectors and matrices, list and data frames, indexing and accessing data, importing and exporting data. Common built-in functions. Simple applications - Descriptive statistics. R-Graphics- Histogram, Box-plot, Stem and leaf plot, Scatter plot, Q-Q plot. Looping-For loop, repeat loop, while loop, if command, if else command.

Unit- 2. Matrices and Standard Probability Distributions: Matrices, rank, determinants and inverse. Eigen values and vectors, power of matrices, g-inverse, system of linear equations, roots of algebraic and transcendental equations. Plotting of cdf and pdf for different values of the parameters of standard distributions. Generations of random samples from standard distributions, demonstrations of the sampling distributions of the standard statistics and functions of random variables-distribution of sample mean and sample variance, illustration of laws of large numbers, central limit theorems.

Unit -3. Sampling Methods: Random sample selections, estimation of mean pro- portion, variance, confidence interval and efficiency under SRS, stratified random sampling, Various kind of allocation, stratification, estimators based on ratio and regression methods pps sampling, two stage cluster sampling, and systematic sampling.

Unit-4.DataAnalysis Using SPSS: SPSS for Windows, using help, dropdown menus of SPSS data editor window, dialog boxes, data structure. Variables and labels, creating and modifying data files. Import of data files, transforming data, selection of random samples, contingency tables. SPSS plots and graphs. The Descriptive statistics, the comparison of means, ANOVA, non-parametric tests, simple correlation and regression procedures.

Books for Study

6. Maria D.U., Ana F.M. and Alan T.A. (2008*): Probability and Statistics with R.* CRC Press.
7. Dalgaard, P. (2008): *Introductory Statistics with R, (Second Edition),* Springer.
8. Hinton PR, Brownlow C, Mc Murray, I.and Cozens, B.(2004): *SPSS Explained,* Routledge, Taylor and Francis group, New York

Reference Books

1. Purohit, S.G, Ghore,S.D and Deshmukh, S.R.(2004): *Statistics Using R*. Narosa.
2. Field, A. (2011); *Discovering Statistics Using SPSS,* Sage Publications.

Semester II

MSSTA02P01 STATISTICAL COMPUTING - II

Course Objectives:	The main objective of this paper is to introduce some advanced statistical computing techniques to extract information and visualization thereby enabling them to perform data analysis effectively and efficiently in R programming.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Equipped with different theoretical methods to achieve the objectives. 2. Enhanced with the basic concepts of statistical theories besides developing their ability to handle real world problems with large scale data.

Unit -1. Testing of Hypothesis: Power function and OC function, parametric and non-parametric tests, single sample tests, two sample tests, test for independence, one way and two-way ANOVA, Sequential Probability Ratio Test

Unit-2. Re-sampling Methods: Bootstrap methods, bias and standard errors, bootstrapping for estimation of sampling distribution, confidence intervals, variance stabilizing transformation, Bootstrapping in regression. Jackknife and cross validation: jackknife in sample surveys.

Unit- 3. Classical and Bayesian Estimation: Maximum likelihood estimation, single parameter and multi-parameter cases, confidence interval estimation, Bayesian estimation - Computation of the posterior, the predictive distribution.

Unit -4. Monte Carlo Methods: The Monte Carlo Method of Computing Integrals, Monte Carlo Methods for Estimation, Markov Chain Monte Carlo Methods, Metropolis-Hastings algorithm, Gibbs sampler.

Books for Study

1. Jim Albert (2007). *Bayesian Computation with R*, New York: Springer-Verlag.
2. Maria L. Rizzo (2008): *Statistical Computing with R*, Chapman & Hall/CRC.
3. Maria D. U., Ana F. M. and Alan T. A. (2008*). Probability and Statistics with R.* CRC Press.
4. Peter Dalgaard (2008). *Introductory Statistics with R, Second Edition, Springer*.

Reference Books

1. Bensal, A. K. (2008): *Bayesian Parametric Inference*, New Age, Delhi.
2. Draper, N. R. and Smith, H. (1998): *Applied Regression Analysis, (3rd Edition)*. John Wiley, New York.
3. Casella, G. and Berger, R.L. (2002). *Statistical Inference, 2nd Edition,* Duxbury, Australia.

Semester III

MSSTA03P01 - STATISTICAL COMPUTING-III

Course Objectives:	The main objective of this paper is to introduce some advanced statistical computing techniques to extract information and visualization thereby enabling them to perform data analysis effectively and efficiently in R programming.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1.Equipped with different theoretical methods to achieve the objectives. 2. Enhanced with the basic concepts of statistical theories besides developing their ability to handle real world problems with large scale data.

Statistical Computing **III** is a practical course. The practical is based on all the elective courses in the third semester.

Semester IV

MSSTA04P01 - STATISTICAL COMPUTING- IV

Course Objectives:	The main objective of this paper is to introduce some advanced statistical computing techniques in applied statistics to extract information and visualization thereby enabling them to perform data analysis effectively and efficiently in R programming.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1.Equipped with different theoretical methods in applied statistics to achieve the objectives. 2. Enhanced with the basic concepts of statistical theories besides developing their ability to handle real world problems with large scale data.

Statistical Computing **IV** is a practical course. The practical is based on all the elective courses in the third and fourth semesters

4.3. THE DETAILED SYLLABUS OF ELECTIVE COURSES

Objective of these courses are to impart the theoretical framework of different applied and interdisciplinary areas of statistics to students.

MSSTA03E01 -ANALYSIS OF CLINICAL TRIALS

Course Objectives:	The objective of this course is to study more advanced topics in design and analysis of clinical trials
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand Basics of Clinical Trails 2. Understand design of clinical trials 3. Understand Sample size determination in clinical trials 4. Understand the concept of meta-analysis in clinical trials

Unit 1. Basics of Clinical Trails: Introduction to clinical trials, the need and ethics of clinical trials, bias and random error in clinical studies, Protocols, conduct of clinical trials, over view of Phase I-IV trials, Data management-data definitions, standard operating procedure, informed consent form, case report forms, database design, data collection systems for good clinical practice.

Unit-2. Design of Clinical Trials: Design of clinical trials- Different phases, Comparative and controlled trials, Random allocation, Randomization, response adaptive methods and restricted randomization. Methods of Blinding, Parallel group designs, Crossover designs, Symmetric designs, Adaptive designs, Group sequential designs, Zelen's designs, design of bioequivalence trials. Outcome measures.

Unit -3. Sample Size Determination and Testing: Sample size determination in one and two sample cases, comparative trials, activity studies, testing and other purposes, unequal sample sizes and case of anova. Surrogate endpoints-selection and design of trials with surrogate endpoints, analysis of surrogate end point data. Reporting and Analysis-Interpretation of result, multi-center trials.

Unit -4. Meta-Analysis: Meta-analysis in clinical trials-concept and goals, fixed and random effect approaches. Bioassay: Direct and indirect assays, Quantal and quantitative assays, Parallel line and slope ratio assays, Design of bioassays.

Books for study

1. Friedman, L. M., Furburg, C. D. Demets, L. (1998): *Fundamentals of Clinical Trials*, Springer Verlag.

2. Jennison and B. W. Turnbull (1999*): Group Sequential Methods with Applications to Clinical Trails,* CRC Press.

3. Kulinskaya E, Morgeathaler S, Staudte R G (2008), *Meta-analysis*, Wiley.

Reference books

1. Das, M. N. and Giri (2008). *Design of Experiments*, New Age, India

2. Fleiss, J. L. (1989): *The Design and Analysis of Clinical Experiments*, Wiley.

3. Marubeni, E. and M. G. Valsecchi (1994): *Analyzing Survival Data from Clinical Trials and Observational Studies*, Wiley and Sons.

4. Piantadosi S. (1997): *Clinical Trials: A Methodological Perspective*. Wiley.

5. W Rosenberger, J MLachin (2002): *Randomization in Clinical Trials Theory and Practice*, Wiley

MSSTA03E02 - ANALYSIS OF LONGITUDINAL DATA

Course Objectives:	The objective of this course is to study more advanced topics in longitudinal data analysis
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Conduct analysis of longitudinal data. 2. Apply statistical techniques to model longitudinal data and make predictions. 3. Understand analysis of longitudinal data with missing data. 4. Understand analysis of longitudinal data with time-dependent covariates.

Unit 1. Linear Model for Longitudinal Data: General Linear Model for Longitudinal Data. ML and REML estimation, EM algorithm: General linear mixed-effects model, Inference for; the random effects, BLUPs, Empirical Bayes, Bayes, Shrinkage Model building and diagnostic, relaxing parametric assumptions: generalized additive mixed model.

Unit- 2. Generalized Linear Model for Longitudinal Data: Generalized Linear Model for Longitudinal Data, Marginal models, for binary, ordinal, and count data: Random effects models for binary and count data: Transition models: Likelihood- based models for categorical data; GEE; Models for mixed discrete and continuous responses.

Unit -3. Longitudinal Data with Missing Data: Classification missing data mechanism; Intermittent missing values and dropouts; Weighted estimating equations; Modeling the dropout process (Selection and pattern mixture models).

Unit-4. Time-dependent Covariates and Special Topics: Dangers of time dependent covariates, Lagged covariates; Marginal Structural models; Joint models for longitudinal and survival data; Multivariate longitudinal data; Design of randomized and observational longitudinal studies.

Books for Study

1. Diggle, P.J., Heagerty, P., Liang, K.Y and Zeger. S.L (2003). *Analysis of Longitudinal Data, 2nd Edn.* Oxford University press, New York.

2. Fitzmaurice, G.M., Laird, N.M and Ware, J.H. (2004). *Applied Longitudinal Analysis*, John Wiley & Sons, New York.

Reference Books

1. Crowder, M.J. and Hand, D.J. (1990). *Analysis of Repeated Measures*. Chapman and Hall/CRC Press, London.

2. Davidian, M. and Giltinan, D.M. (1995). *Nonlinear Models for Repeated Measurement Data.* Chapman and Hall/CRC Press, London.

3. Hand,D and Crowder, M. (1996). *Practical Longitudinal Data Analysis.* Chapman and Hall/CRC Press, New York.

4. Little, R. J. A and Rubin, O.B. (2002). *Statistical Analysis with Missing Data, 2nd Edition,* Wiley, New York.

5. Mc Cullagh,P. and Nelder. J. A. (1989*). Generalized Linear Models. 2nd Edition,* Chapman and Hall/CRC Press, London.

6. Weiss, R.E. (2005*). Modeling Longitudinal Data. Springer*, New York

MSSTA03E03 - APPLIED REGRESSION ANALYSIS

Course Objectives:	This course provides the students the ability to understand the regression methods, as well as to analyze and interpret data.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand various regression models including logistic regression models and simultaneous equation models. 2. Understand consequences of multicollinearity, heteroscedasticity, autocorrelation, their detection and remedial measures. 3. Apply statistical techniques to model relationships between variables and make predictions. 4. Acquire knowledge of various advanced econometric models, estimation methods and related econometric theories. 5. Conduct econometric analysis of data.

Unit -1. Linear Regression Models: The simple linear regression models, least square estimation, statistical assumptions and properties of estimators, standard error of estimates, tests of significance and confidence intervals for the parameters, error and residual plots.

Unit-2. Regression Diagnostics: Multicollinearity, heteroscedasticity, autocorrelation: their nature, consequences, detection, remedial measures and estimation in the presence of them. Multiple regression models, OLS and ML estimators, testing and prediction.

Unit-3. Nonparametric Regression and Simultaneous Equation Models: Nonparametric regression - Nonparametric regressions and concept of spline smoothing. Simultaneous equation models - examples, inconsistency of OLS estimators, identification problem, rules for identification, method of indirect least squares, method of two stage least squares.

Unit -4. Non-Linear Regression: Polynomial regression in one and several variables. Linearization transforms, Diagnostic checks and correction. Generalized linear models. Logistic regression.

Books for Study

1. Draper, N. R. and Smith, H. (1998): *Applied Regression Analysis, 3rd Ed.* John Wiley.

2. Gujarati, D.N. (2007): *Basic Econometrics (Fourth Edition)*, McGraw- Hill, New York.

3. Hosmer, D.W. and Lemeshow, S. (1989): *Applied Logistic Regression*, John Wiley.

4. Montgomery, D .C, Peek, E. A. and Vining, G. G. (2006): *Introduction to Linear Regression Analysis*, John Wiley.

Reference Books

1. Seber, G. A. F. and Lee, A. J. (2003): *Linear Regression Analysis*, Wiley

2. Johnston, J. (1984): *Econometric Methods, 3rd ed.,* McGraw Hill, New York.

3. Goon, Gupta, Das Gupta (2001): *An Outline Series in Statistics Vol II,* World Press.

MSSTA03E04-RELIABILITY MODELING

Course Objectives:	**The objective of this course is to study more advanced topics in reliability modelling**
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand reliability concepts and measures 2. Understand various lifetime Probability distributions and their structural properties 3. Understand univariate and bivariate shock models and reliability estimation based on failure times 4. Understand Maintenance and Replacement Policies

Unit1.BasicReliabilityConcepts: Reliabilityconceptsandmeasures; components andsystems;coherentsystems;reliabilityofcoherentsystems; cutsandpaths; modular decomposition; bounds on reliability; structural and reliability importance of components.

Unit- 2.Life Distributions andProperties: Life distributions; reliability function; hazard rate; common life distributions-exponential, Weibull, Gamma etc. Estimation of parameters and tests in these models. Notions of ageing; IFR, IFRA, NBU, DMRL, and NBUE Classes and their duals; closures or these classes under formation of coherent systems, convolutions and mixtures.

Unit -3. Shock Models: Univariate shock models and life distributions arising out of them; bi-variate shock models; common bivariate exponential distributions and their properties. Reliability estimation based on failure times in variously censored lifetestsandintestswithreplacementoffaileditems;stress-strengthreliabilityand itsestimation.

Unit -4. Maintenance and Replacement Policies: Repairablesystems,replacement policies, modeling of a repairable system by a non-homogeneous Poisson process. Reliabilitygrowthmodels;probabilityplottingtechniques;Hollander-Proschanand Deshpande tests for exponentiality; tests for HPP vs. NHPP with repairable systems. Basic ideas of accelerated lifetesting.

Book for Study

1. Barlow R.E. and ProschanF.(1985). *Statistical Theory of Reliability and Life Testing*; Holt,Rinehart and Winston.

Reference Books

1. Bain L.J. and Engelhardt (1991). *Statistical Analysis of Reliability and Life Testing Models;* Marcel Dekker.

2. Aven,T.andJensen,U. (1999).*StochasticModelsinReliability*, Springer Verlag, New York,Inc.

3. Nelson, W (1982).*Applied Life Data Analysis*; JohnWiley.

4. Zacks, S. (1992). *Introduction to Reliability Analysis: Probability Models and Statistics Methods.* New York:Springer-Verlag.

MSSTA03E05- OPERATIONS RESEARCH

Course Objectives:	The main course objective of this paper is to introduce quantitative and model based techniques for model formulation and effective decision–making.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Identify and develop operational research models from the verbal description of the real system. 2. Understand the mathematical tools that are needed to solve optimization problems. 3. Understand various methods in Integer programming and Game theory

Unit 1. Algebra of linear programming problems: Introduction to linear programming problem (LPP), graphical solution, feasible, basic feasible, and optimum basic feasible solution to an LPP. Analytical results in general LPP, theoretical development of simplex method.

Unit- 2. Duality and Dual Simplex Method: Artificial variables, Big-M method, two phase simplex method Duality, duality theorems, dual simplex methods. Transportation problem, assignment problem.

Unit-3. Integer Programming and Network Analysis: Integer programming: Cutting plane methods, branch and bound technique. Network analysis, Critical path analysis, -CPM, PERT, distinction between CPM and PERT.

Unit -4. Game Theory: Game theory, pure and mixed strategies, conversion of two-person zero gain to a linear programming problem. Solution to game through algebraic, graphical and linear programming method,

Books for Study

1. K.V. Mital and Mohan, C (1996). *Optimization Methods in Operations Research and Systems Analysis, 3rd Edition,* New Age International (Pvt.) Ltd.

2. Kanti Swamp, Gupta, P.K. and John, M. M. (1985): *Operations Research.,* Sultan Chand & Sons.

Reference Books

1. Hadley, G. (1964). *Linear Programming*, Oxford & IBH Publishing Co, New Delhi.

2. Taha. H. A. (1982): *Operation Research, An Instruction*, Macmillan.

3. Hiller F. S. And Lieberman, G.J. (1995*). Introduction to Operations Research,* McGraw Hill

MSSTA04E06-ADVANCED DISTRIBUTION THEORY

Course Objectives:	The objective of this course is to study more advanced topics in distribution theory
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand different systems of distributions as generalizations of various standard continuous distributions. 2. Understand various characterizations of probability distributions. 3. Understand the concept of generalized power series distribution as generalization of various discrete distributions. 4. Understand the idea of mixture distributions and non-parametric density estimation.

Unit 1. Systems of Distributions: Pearson system of frequency curves, determination of parameters, the kappa criterion, properties and extensions, estimation of parameters. The Johnson's system, Burr's system, distributions based on series expansion, Edgeworth series, Gram Charlier series.

Unit- 2. Characterization of Probability Laws: Characterization of probability distribution, Exponential and Geometric law, lack of memory property, normal law - characterization based on independence of linear forms and quadratic forms and regression.

Unit -3.Generalized Power Series Distributions: power series and compound distributions. Generalized Poisson distribution, Hyper Poisson family, distributions derived from Poisson and other generalization.

Unit -4. Mixture Distributions and Non - parametric density estimation: Finite and infinite mixtures, identifiability of mixtures, examples of non-identifiable mixtures, finite normal mixtures and estimation, normal mixture regression models. Density estimation, histogram and nave estimate, Kernel density estimate and properties.

Books for Study

1. Johnson, N.L., Kotz, S. and Balakrishnan, N. (1995). *Continuous Univariate Distributions, Vol.I &Vol.II,* John Wiley and Sons, New-York.

2. MacLachlan, P. and Peel, D. (2000). *Finite Mixture Models*. John Wiley& Sons, New York

3. Silverman, B. (1986). *Density Estimation for Statistics and Data Analysis*. Chapman &Hall.

Reference Books

1. Johnson, N.L., Kotz. S. and Kemp. A.W. (1992). *Univarite Discrete Distributions, John* Wiley and Sons, New York.

2. Stuart, A. Ord, A. (1994). *Kendall's Advanced Theory of Statistics, Distribution Theory, 6th Edition.* Wiley-Blackwell.

3. Kagan A.M., Linnik, Y.V. and Rao C.R. (1975). *Characterization Problems in Mathematical Statistics*. John Wiley.

MSSTA04E07-ADVANCED BAYESIAN COMPUTING WITH R

Course Objectives:	The objective of this course is to study more advanced topics in Bayesian computing and data analysis using R
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the advantageous Bayes estimation over that based on frequentist approach. 2. Understand the LearnBayes package for various Bayesian computations 3. Understand MCMC methods in various situations in which the exact computation is difficult. 4. Understand Gibbs sampling to generate random samples from a multivariate distribution.

Unit1. Bayesian Inference: Statistical decision problem, randomized decision rule, decision principle, standard loss functions, Prior information, subjective determination of prior density, non-informative priors, maximum entropy priors, conjugate priors, discrete prior. Parametric family and likelihood, exponential family, Bayes' theorem for inference, prior and posterior densities.

Unit- 2. Single and multi-parameter models: single parameter models, normal distribution with known variance and unknown mean, normal with known mean and unknown variance, Poisson model, normal distribution with both parameters unknown, multinomial model, Dirichlet prior, Bioassay experiment, comparing two proportions, predictive distribution, beta-binomial distribution, multivariate normal distribution, introduction to Learn Bayes package, Examples using Learn Bayes package.

Unit-3. Bayesian Computation: Computing integrals using Monte-Carlo simulation, approximation based on posterior mode, importance sampling, Markov Chain Monte Carlo methods, Metropolis-Hastings algorithm, random walk, Gibbs sampling.

Unit -4. Model Comparison and Regression models: Hierarchical models, shrinkage estimators, posterior predictive model checking, comparison of hypotheses, Bayes factor, one sided test for normal mean, two sided test for normal mean, normal linear regression model, prediction of future observations, examples and R codes, introduction to Win-BUGS package.

Books for Study

1. Jim Albert (2007). *Bayesian Computation with R*, New York: Springer Verlag.
2. Berger, O. J. (1985). *Statistical decision Theory and Bayesian Analysis, Second Edition,* Springer Verlag.
3. Bensal, A. K. (2008*). Bayesian Parametric Inference*, New Age, Delhi.

Reference books

1. Ferguson, T.S. (1967*).MathematicalStatistics:ADecision-TheoreticApproach*, Academic Press, New-York.
2. Bolstad, W. (2004*). Introduction to Bayesian Statistics*, Hoboken, N J: John Wiley.
3. Gelman, A., Carlin, J., Stern, H.and Rubin, D. (2003). *Bayesian Data Analysis,* New York: Chapman andHall.
4. Gilks, W. R., Richardson, S and Spiegelhalter, D.J. (1996). *Markov Chain Monte Carlo in Practice.* Chapman & Hall/CRC, New York.
5. Robert, C. and Casella, G. (2004).*Monte Carlo Statistical Methods*, New York: Springer
6. Spiegelhalter, D., Thomas, A., Best, N. and Lunn, D. (2003), *Win- BUGS 1.4 Manual*

MSSTA04E08 **-MIXTURE REGRESSION MODELS**

Course Objectives:	The objective of this course is to study advanced topics in mixture regression models as a generalization of ordinary regression.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand concept of finite mixture regression models with emphasis on its applications. 2. Understand the problem of non-identifiability of mixture models 3. Understand the EM algorithm for the estimation of parameters of mixture regression models and generalized linear mixture models. 4. Work with various R-packages for the analysis of mixture models.

Unit-1 Mixture Distributions: Finite and infinite mixtures, location and scale mixtures, non-identifiable mixtures, examples of non-identifiable mixtures, condition for identifiability when the components belong to power series family.

Unit-II Simulation and Estimation: Finite normal, Poisson and negative binomial mixtures, simulation of random samples from mixtures, applications of mixture models. Estimation of parameters of mixture models, method of moments, maximum likelihood estimation, EM algorithm.

Unit-III Mixture Regression: Normal mixture regression, Poisson mixture regression, estimation of parameters, examples using real and simulated data, r packages, FlexMix, Mixtools and CAMAN.

Unit-IV Generalized Linear Mixture Models: Exponential family, generalized linear models, examples, generalized linear mixture models, logistic and mixture logistic models, concomitant variables and varying parameter cases.

Books for Study

1. McLachlan, G.J. and Peel, D. (2000). *Finite Mixture Models*. John Wiley & Sons, INC, New York.

Reference Books

1. Schlattmann, P. (2009). *Medical Applications of Finite Mixture Models.* Springer Verlag Berlin Heidelberg.
2. Titterington, D. M., Smith, A. and Makov, U. (1985). *Statistical Analysis of Finite Mixture Distributions.* New York: Wiley
3. Leisch, F. (2004). Flex Mix: A general framework for finite mixture models and latent class regression in R. *Journal of Statistical Software,*11(8), 1-18. http://www.jstatsoft.org/
4. Wang, P. et.al. (1996). Mixed Poisson regression models with covariate dependent rates. *Biometrics*, 52, 381-400.
5. Sapatinas, T. (1995). Identifiability of mixtures of power-series distributions and related characterizations. *Ann. Inst. Statist. Math.,*47 (3), 447-459.
6. McLachlan, G. J. and Krishnan, T. (1997). *The EM algorithm and Extensions*. New York: Wiley.

MSSTA04E09-QUEUEING THEORY

Course Objectives:	The objective of this course is to study more advanced topics in Queueing theory
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand various Markovian queueing models and their analysis 2. Understand transient behaviour of queueing models and analysis of advanced Markovian models with bulk arrival and bulk service

	3. Understand various queueing networks and their extensions 4. Understand various non Markovian queueing models and their analysis

Unit 1. Markovian Queueing Models: Introduction to queueing theory, Characteristics of queueing processes, Measures of effectiveness, Markovian queueing models, steady state solutions of the M/M/I model, waiting-time distributions, Little's formula, queues with unlimited service, finite source queues.

Unit- 2. Advanced Markovian Models: Transient behavior of M/M/1 queues, transient behavior of M/M/1. Busy period analysis for M/M/1 and M/M/c models. Advanced Markovian models. Bulk input M[X] /M/1 model, Bulk service M/M[Y]/1 model, Erlangian models, M/Ek/1and Ek/M/1. A brief discussion of priority queues.

Unit -3. Queueing Networks; Series queues, open Jackson networks, closed Jackson network, Cyclic queues, Extension of Jackson networks. Non-Jackson networks.

Unit -4. Non Markovian Queueing Models: Models with general service pattern, The M/G/1 queueing model, The Pollaczek-Khintchine formula, Departure point steady state systems size probabilities, ergodic theory, Special cases M/Ek/1 and M/D/1, waiting times, busy period analysis, general input and exponential service models, arrival point steady state system size probabilities.

Books for Study

1. Gross, D. and Harris, C.M. (1985): *Fundamentals of Queueing Theory, 2nd Edition,* John Wiley and Sons, New York.

Reference books

1. Ross, S.M. (2010). Introduction to Probability Models. 10th Edition, Academic Press, New York.

2. Bose, S.K. (2002). An Introduction to Queueing Systems, Kluwer Academic / Plenum Publishers, New York.

MSSTA04E10 -LIFETIME DATA ANALYSIS

Course Objectives:	The objective of this course is to study more advanced topics in life time data analysis
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand various lifetime probability distributions and their structural properties 2. Understand different methods for the estimation of survival function. 3. Conduct analysis of time data 4. Apply statistical techniques to model lifetime data and make predictions.

Unit 1. Lifetime Distributions: Lifetime distributions, Important parametric models, Exponential Weibull, Log-normal, Log-logistic, Gamma, Inverse Gaussian distributions, Log-location scale models and mixture models. Censoring and statistical methods.

Unit- 2. Estimation of Survival Function: The product-limit estimator and its properties. The Nelson-Aalen estimator, interval estimation of survival probabilities, asymptotic properties of estimators, descriptive and diagnostic plots, estimation of hazard function, methods for truncated and interval censored data, Life tables.

Unit -3. InferenceProcedures: Inference under exponential model - large sample theory, type-2 censored test plans, comparison of two distributions; inference procedures for Gamma distribution; models with threshold parameters, inference for log- location scale distribution: likelihood based methods: Exact methods under type-2 censoring; application to Weibull and extreme value distributions, comparison of distributions.

Unit -4. Regression Models: Log-location scale (Accelerated Failure time) model, Proportional hazard models, Methods for continuous multiplicative hazard models, Semi-parametric maximum likelihood estimation of continuous observations, Incomplete data; Rank test for comparing Distributions, Log-rank test, Generalized Wilcox on test. A brief discussion on multivariate lifetime models.

Books for Study

1. Lawless, J.F. (2003): *Statistical Methods for Lifetime (Second Edition), John*Wiley & Sons Inc., New Jersey.

2. Kalbfiesche, J. D. and Prentice, R.L. (1980): *The Statistical Analysis of Failure Time Data,* John Wiley & Sons Inc. New Jersey.

Reference Books

1. Miller, R.G. (1981): *Survival Analysis*, John Wiley & Sons Inc.

2. Bain, L.G. (1978*): Statistical Analysis of Reliability and Life testing Models*, Marcel Decker.

3. Cox, D.R and Oakes, D. (1984): *Analysis of Survival Data*. Chapman and Hall.

MSSTA04E11-STATISTICAL QUALITY CONTROL

Course Objectives:	The objective of this course is to study more advanced topics in statistical quality control
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the construction various control charts and their real data applications. 2. Understand various process capability indices and their applications. 3. Understand various different acceptance sampling plans for attributes and variables.

Unit 1. Control Charts: Statistical process control, theory of control charts, Shewhart control charts for variables, R, s charts, p, np, c, u charts, modified control charts.

Unit- 2. Process Capability Analysis: O.C and ARL curves of control charts, moving average control charts, EWMA charts, CUSUM charts, process capability analysis, process capability indices.

Unit -3. Acceptance Sampling For Attributes, : Single sampling, double sampling, multiple sampling and sequential sampling plans, rectifying inspection plans, measuring performance of the sampling plans - OC,

AOQ, ASN, ATI curves.

Unit-4. Acceptance Sampling by Variables: Sampling plans for single specification limit with known and unknown and unknown variance. Sampling plans with double specification limits., comparison of sampling plans by variables and attributes, Continuous sampling plans I, II and III.

Books for study

1. Montgomory, D.C. (2005), *Introduction to Statistical Quality Control. 5th Edition.* Wiley, New-York.

2. Gerant, E.L. and Leaven Worth, R.S. (1980). *Statistical Quality Control.* McGraw Hill

Reference books

1. Mittage, H.J. and Rinne, H. (1993). *Statistical Methods for Quality Assurance*. Chapman and Hall.

2. Oakland, J. S. and Follorwel, R.F. (1990). *Statistical Process Control*. East-West Press.

3. Schilling, E.G. (1982). *Acceptance Sampling in Quality Control*. Marcel Dekker.

MSSTA04E12- TIME SERIES ANALYSIS

Course Objectives:	The objective of this course is to study advanced topics in time series
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand exploratory time series analysis and its real data application. 2. Understand autoregressive models and their estimation methods. 3. Understand non-linear time series models and their estimation methods. 4. Apply statistical techniques to time series data and make predictions.

Unit 1. Time Series Basic Concepts: Motivation, Time series as a discrete parameter stochastic process, Auto-Covariance, Auto-Correlation and spectral density and their properties. Exploratory time series analysis, Test for trend and seasonality, Exponential and moving average smoothing, Holt - Winter smoothing, forecasting based on smoothing, Adaptive smoothing.

Unit- 2. Autoregressive Models: Detailed study of the stationary process: Autoregressive, Moving Average, Autoregressive Moving Average and Autoregressive Integrated Moving Average Models. Choice of AR / MA

periods.

Unit -3. Estimation of ARMA and ARIMA Models: Estimation of ARMA models: Yule - Walker estimation for AR Processes, Maximum likelihood and least square estimation for ARMA Processes, Discussion (without proof) of estimation of mean, Auto- covariance and autocorrelation function under large samples theory, Residual analysis and diagnostic checking. Forecasting using ARIMA models.

Unit -4. Non-Linear Time Series Models: Spectral analysis of weakly stationary process. Periodogram and correlogram analysis. Seasonal ARIMA models (Basic concepts only), ARCH and GARCH models (Basic concepts only)

Books for Study

1. Box G.E.P and Jenkins G.M. (1970). *Time Series Analysis, Forecasting and Control.* Holden-Day.

2. Brockwell P.J.and Davis R.A. (1987). *Time Series: Theory and Methods*, Springer Verlag.

Reference books

1. Abraham B and Ledolter J.C. (1983).Statistical Methods for Forecasting, Wiely

2. Anderson T.W. (1971). *Statistical Analysis of Time Series*,Wiely.

3. Fuller W.A. (1978). *Introduction to Statistical Time Series,* John Wiley.

5. OPEN ELECTIVE COURSES

Students can join for the open course depending on their choice and availability of seats in the departments offering such courses. Open Elective Courses will be offered by other Departments/Centres/Institutions as options. Open Courses can be opted in any of the Semesters during the entire programme other than the first semester.

Objective of these courses are to impart the theoretical frame work of different statistical procedures to students of other discipline and enhance their working knowledge of various statistical soft-wares like R and SPSS, thereby enabling them to perform data analysis effectively. Post graduate students of other disciplines are eligible to join this course.

LIST OF OPEN ELECTIVE COURSES			
COURSE CODE	COURSE TITLE	L-T-P	Total Credit
MSSTA03O01	Statistical Methods Using R and SPSS	4-0-0	4
MSSTA03O02	Stochastic Processes	4-0-0	4
MSSTA03O03	Applied Regression Analysis	4-0-0	4
MSSTA03O04	Bayesian Computing with R	4-0-0	4
MSSTA03O05	Mixture Regression Models	4-0-0	4
MSSTA03O06	Statistical Quality Control	4-0-0	4

5.1. THE DETAILED SYLLABUS OF OPEN ELECTIVE COURSES

MSSTA03O01 -STATISTICAL METHODS USING R AND SPSS

Course Objectives:	The objective of this courses is to enhance the programming skills and working knowledge of available statistical software and programming languages.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand various built-in functions in R programming for statistical data analysis. 2. Understand different functions in R programming for writing computer programmes and develop computer programmes for different problems 3. Understand the usage of menus in SPSS window for drawing various diagrams and computing descriptive statistics, the comparison of means, ANOVA, non-parametric tests, simple correlation and regression procedures and apply for real data sets.

Unit 1. Basic Concepts of R Programming: Introduction to R- Objects and their classes, operators, vectors and matrices, list and data frames, indexing and accessing data, importing and exporting data. Common built-in functions. Simple applications - Descriptive statistics. R-Graphics- Histogram, Box-plot, Stem and leaf plot, Scatter plot, Q-Q plot. Looping-For loop, repeat loop, while loop, if command, if else command.

Unit- 2. Data Analysis Using R: Basic concepts of probability and random variables, Probability distributions (Binomial, Poisson, Geometric, Uniform, Normal, Gamma, Beta), Plotting of cdf and pdf for different values of the parameters of standard distributions. Generations of random samples from standard distributions. The Descriptive statistics, the comparison of means, ANOVA, non-parametric tests, correlation and regression procedures.

Unit -3. Sampling Methods: Random sample selections, estimation of mean pro- portion, variance, confidence interval and efficiency under SRS, stratified random sampling, Various kind of allocation, stratification, estimators based on ratio and regression methods pps sampling, two stage cluster sampling, and systematic sampling.

Unit-4. Data Analysis Using SPSS: SPSS for Windows, using help, dropdown menus of SPSS data editor window, dialog boxes, data structure. Variables and labels, creating and modifying data files. Import of data files, transforming data, selection of random samples, contingency tables. SPSS plots and graphs. The Descriptive statistics, the comparison of means, ANOVA, non-parametric tests, correlation and regression procedures.

Books for Study

1. Maria D.U., Ana F.M. and Alan T.A. (2008*): Probability and Statistics with R.* CRC Press.
2. Dalgaard, P. (2008): *Introductory Statistics with R, (Second Edition),* Springer.
3. Hinton PR, Brownlow C, Mc Murray, I.and Cozens, B.(2004): *SPSS Explained,* Routledge, Taylor and Francis group, New York

Reference Books

1. Purohit, S.G, Ghore,S.D and Deshmukh, S.R.(2004): *Statistics Using R*. Narosa.

2. Field, A. (2011); *Discovering Statistics Using SPSS,* Sage Publications.

MSSTA03O02 - STOCHASTIC PROCESSES

Course Objectives:	The main objective of this course is to develop awareness for the use of stochastic models for representing random phenomena evolving in time such as Poisson, Renewal, Branching, Queueing and Brownian motion process.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the concepts of Stochastic processes. 2. Understand the concepts of Markov chains, classification of its states and limiting probabilities. 3. Understand continuous time Markov chains, Poisson processes and its generalizations. 4. Understand the branching processes, various queueing models and Brownian motion process.

Unit 1. Basics Concepts of Stochastic Processes and Markov Chains: Concept of stochastic processes, examples, stationary and weakly stationary processes. Markov chains- Chapman Kolmogorov equations - classification of states - limiting probabilities; gamblers ruin problem and random walk, Branching processes (discrete time).

Unit- 2. Poisson Processes and Generalizations: Exponential distribution, counting process, inter arrival time and waiting time distributions. Properties of Poisson processes- Conditional distribution of arrival times. Generalizations of Poisson processes, non-homogenous Poisson process, compound Poisson process.

Unit -3. Continuous time Markov Chains and Renewal Processes: Continuous time Markov Chains- Birth and death processes, transition probability function, limiting probabilities. Renewal processes, limit theorems and their applications. Semi- Markov process.

Unit -4. Queueing and Brownian Motion Process: Basic characteristics of queues, analysis of Markovian models (M/M/1, M/M/1/N, M/M/c), network of queues. The M/G/I system and G/M/I model. Brownian motion process

Books for study

1. Ross, S. M. (2010). *Introduction to Probability Models. X th Edition*, Academic Press.
2. Medhi, J. (2009). *Stochastic Processes. Third Edition*. New Academic Science Limited. U K.

Reference books

1. Basu, A.K. (2002). *Elements of Stochastic Processes*, Narosa Publications.
2. Cinlar, E. (1975). *Introduction to Stochastic Processes*. Prentice Hall. New Jersey.

3. Feller, W. (1965, 1968), *An Introduction to Probability Theory and Its Applications, Volume I and II*, Wiley Eastern.
4. Karlin, S. and Taylor, H.M. (1975). *A First Course in Stochastic Processes*. *Second Edition*, Academic Press. New-York.

MSSTA03O03 – APPLIED REGRESSION ANALYSIS

Course Objectives:	This course provides the students the ability to understand the regression methods, as well as to analyze and interpret data.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand various regression models including logistic regression models and simultaneous equation models. 2. Understand consequences of multicollinearity, heteroscedasticity, autocorrelation, their detection and remedial measures. 3. Apply statistical techniques to model relationships between variables and make predictions.

Unit -1. Linear Regression Models: The simple linear regression models, least square estimation, statistical assumptions and properties of estimators, standard error of estimates, tests of significance and confidence intervals for the parameters, error and residual plots.

Unit-2. Regression Diagnostics: Multicollinearity, heteroscedasticity, autocorrelation: their nature, consequences, detection, remedial measures and estimation in the presence of them.

Unit-3. Multiple regression models and Nonparametric regression: Multiple regression models, OLS and ML estimators, testing and prediction. Nonparametric regression - Nonparametric regressions and concept of spline smoothing.

Unit -4. Non Linear Regression: Polynomial regression in one and several variables. Linearization transforms, Diagnostic checks and correction. Generalized linear models. Logistic regression.

Books for Study

1. Draper, N. R. and Smith, H. (1998): *Applied Regression Analysis, 3rd Edition.* John Wiley.
2. Montgomery, D .C, Peek, E. A. and Vining, G. G. (2006): *Introduction to Linear Regression Analysis*, John Wiley.

Reference Books

1. Gujarati, D.N. (2007): *Basic Econometrics (Fourth Edition)*, McGraw- Hill, New York.
2. Goon, Gupta, Das Gupta (2001): *An Outline Series in Statistics Vol II,* World Press.
3. Hosmer, D.W. and Lemeshow, S. (1989): *Applied Logistic Regression*, John Wiley.

MSSTA03O04-ADVANCED BAYESIAN COMPUTING WITH R

Course Objectives:	The objective of this course is to study more advanced topics in Bayesian computing and data analysis using R
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the advantageous Bayes estimation over that based on frequentist approach. 2. Understand the LearnBayes package for various Bayesian computations 3. Understand MCMC methods in various situations in which the exact computation is difficult. 4. Understand Gibbs sampling to generate random samples from a multivariate distribution.

Unit-1. Bayesian Inference: Statistical decision problem, randomized decision rule, decision principle, standard loss functions, Prior information, subjective determination of prior density, non-informative priors, maximum entropy priors, conjugate priors, discrete prior. Parametric family and likelihood, exponential family, Bayes' theorem for inference, prior and posterior densities.

Unit- 2. Single and multi-parameter models: single parameter models, normal distribution with known variance and unknown mean, normal with known mean and unknown variance, Poisson model, normal distribution with both parameters unknown, multinomial model, Dirichlet prior, Bioassay experiment, comparing two proportions, predictive distribution, beta-binomial distribution, multivariate normal distribution, introduction to Learn Bayes package, Examples using Learn Bayes package.

Unit-3. Bayesian Computation: Computing integrals using Monte-Carlo simulation, approximation based on posterior mode, importance sampling, Markov Chain Monte Carlo methods, Metropolis-Hastings algorithm, random walk, Gibbs sampling.

Unit -4. Model Comparison and Regression models: Hierarchical models, shrinkage estimators, posterior predictive model checking, comparison of hypotheses, Bayes factor, one sided test for normal mean, two-sided test for normal mean, normal linear regression model, prediction of future observations, examples and R codes,

introduction to Win-BUGS package.

Books for Study

1. Jim Albert (2007). *Bayesian Computation with R*, New York: Springer Verlag.
2. Berger, O. J. (1985). *Statistical decision Theory and Bayesian Analysis, Second Edition,* Springer Verlag.
3. Bensal, A. K. (2008*). Bayesian Parametric Inference*, New Age, Delhi.

Reference books

1. Ferguson, T.S. (1967*). Mathematical Statistics: A Decision Theoretic Approach*, Academic Press, New-York.
2. Bolstad, W. (2004*). Introduction to Bayesian Statistics*, Hoboken, N J: John Wiley.
3. Gelman, A., Carlin, J., Stern, H.and Rubin, D. (2003). *Bayesian Data Analysis,* New York: Chapman andHall.
4. Gilks, W. R., Richardson, S and Spiegelhalter, D.J. (1996). *Markov Chain Monte Carlo in Practice.* Chapman & Hall/CRC, New York.
5. Robert, C. and Casella, G. (2004). *Monte Carlo Statistical Methods*, New York: Springer
6. Spiegelhalter, D., Thomas, A., Best, N. and Lunn, D. (2003), *Win- BUGS 1.4 Manual*

MSSTA03O05 **-MIXTURE REGRESSION MODELS**

Course Objectives:	The objective of this course is to study advanced topics in mixture regression models as a generalization of ordinary regression.
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand concept of finite mixture regression models with emphasis on its applications. 2. Understand the problem of non-identifiability of mixture models 3. Understand the EM algorithm for the estimation of parameters of mixture regression models and generalized linear mixture models. 4. Work with various R-packages for the analysis of mixture models.

Unit-1 Mixture Distributions: Finite and infinite mixtures, location and scale mixtures, non-identifiable mixtures, examples of non-identifiable mixtures, condition for identifiability when the components belong to power series family.

Unit-II Simulation and Estimation: Finite normal, Poisson and negative binomial mixtures, simulation of random samples from mixtures, applications of mixture models. Estimation of parameters of mixture models, method of moments, maximum likelihood estimation, EM algorithm.

Unit-III Mixture Regression: Normal mixture regression, Poisson mixture regression, estimation of parameters, examples using real and simulated data, r packages, FlexMix, Mixtools and CAMAN.

Unit-IV Generalized Linear Mixture Models: Exponential family, generalized linear models, examples, generalized linear mixture models, logistic and mixture logistic models, concomitant variables and varying parameter cases.

Books for Study

1. McLachlan, G.J. and Peel, D. (2000). *Finite Mixture Models*. John Wiley & Sons, INC, New York.

Reference Books

1. Schlattmann, P. (2009). *Medical Applications of Finite Mixture Models.* Springer Verlag Berlin Heidelberg.
2. Titterington, D. M., Smith, A. and Makov, U. (1985). *Statistical Analysis of Finite Mixture Distributions.* New York: Wiley
3. Leisch, F. (2004). Flex Mix: A general framework for finite mixture models and latent class regression in R. *Journal of Statistical Software,*11(8), 1-18. http://www.jstatsoft.org/
4. Wang, P. et.al. (1996). Mixed Poisson regression models with covariate dependent rates. *Biometrics*, 52, 381-400.
5. Sapatinas, T. (1995). Identifiability of mixtures of power-series distributions and related characterizations. *Ann. Inst. Statist. Math.,*47 (3), 447-459.
6. McLachlan, G. J. and Krishnan, T. (1997). *The EM algorithm and Extensions*. New York: Wiley.

MSSTA03O06-STATISTICAL QUALITY CONTROL

Course Objectives:	The objective of this course is to study more advanced topics in statistical quality control
Course Learning Outcomes:	After successful completion of this course, student will be able to: 1. Understand the construction various control charts and their real data applications.

	2. Understand various process capability indices and their applications. 3. Understand various different acceptance sampling plans for attributes and variables.

Unit 1. Control Charts: Statistical process control, theory of control charts, Shewhart control charts for variables, R, s charts, p, np, c, u charts, modified control charts.

Unit- 2. Process Capability Analysis: O.C and ARL curves of control charts, moving average control charts, EWMA charts, CUSUM charts, process capability analysis, process capability indices.

Unit -3. Acceptance Sampling for Attributes: Single sampling, double sampling, multiple sampling and sequential sampling plans, rectifying inspection plans, measuring performance of the sampling plans - OC, AOQ, ASN, ATI curves.

Unit-4. Acceptance Sampling by Variables: Sampling plans for single specification limit with known and unknown and unknown variance. Sampling plans with double specification limits., comparison of sampling plans by variables and attributes, Continuous sampling plans I, II and III.

Books for study

1. Montgomory, D.C. (2005), *Introduction to Statistical Quality Control. 5th Edition.* Wiley, New-York.
2. Gerant, E.L. and Leaven Worth, R.S. (1980). *Statistical Quality Control.* McGraw Hill

Reference books

1. Duncan, A.J. (1986). *Quality Control and Industrial Statistics*.
2. Mittage, H.J. and Rinne, H. (1993). *Statistical Methods for Quality Assurance*. Chapman and Hall.
3. Oakland, J. S. and Follorwel, R.F. (1990). *Statistical Process Control*. East-West Press.
4. Schilling, E.G. (1982). *Acceptance Sampling in Quality Control*. Marcel Dekker.