Choice Based Credit System (CBCS)

UNIVERSITY OF DELHI

DEPARTMENT OF STATISTICS

Master of Statistics
(M.A./M.Sc. Statistics)

(Effective from Academic Year 2018-19)

Proposed Syllabus

XXXXX Revised Syllabus as approved by Academic Council on XXXX, 2018 and Executive Council on YYYY, 2018

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I. About the Department

The Department of Mathematical Statistics was established in August 1973, though the teaching of M.A. in Mathematical Statistics had been introduced as early as in July 1957 at the initiative of Professor Ram Behari as part of a development programme adopted by the Department of Mathematics. Professor H.C. Gupta was the first head of the Department and he can be credited with the setting up of a good school in Stochastic Processes. . In 1971, the scope of post-graduate course in Mathematical Statistics was extended leading to M.Sc. degree in Statistics.

In 1987, the Department of Mathematical Statistics was re-named as the Department of Statistics. The Department is running the post-graduate (M.A./M.Sc.), M.Phil. and Ph.D. programmes in Statistics.

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. With a view to preparing research background of the students, the M.Phil. Course in Mathematical Statistics was introduced in 1977 and the same has been continually updated covering most of the areas of Theoretical and Applied Statistics at the specialization level.

The Department has laboratories equipped with the basic and modern computing facilities. There is a good collection of books in department with latest titles in various areas of statistics. Two computer laboratories with latest computing systems and related equipment have been setup in the Department for the use of students, research scholars and teachers. Regarding the job opportunities, the Department has a placement cell operating since academic year 2005-06. The department also has Research Activity Cell, UDAAN-The Socio-Cultural cell and Heritage Club operating since the academic year 2016-17. We can take pride in the fact that students get suitable placement in Research Institutes or Industries or Government Departments. Significant number of students are selected in the prestigious Indian Statistical Service (ISS) each year.

II. Introduction to CBCS (Choice Based Credit System)

Choice Based Credit System:

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.

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 programmes, including students of same department. 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 at any point of time. CGPA is calculated each year for both the semesters clubbed together.

(x) 'Grand CGPA' is calculated in the last year of the course by clubbing together of CGPA of two years, i.e., four semesters. Grand CGPA is being given in Transcript form. To benefit the student a formula for conversation of Grand CGPA into %age marks is given in the Transcript.

Programme Objectives (PSOs):

1. To inculcate and develop aptitude to apply statistical tools at a number of data generating fields in real life problems.
2. To train students to handle large data sets and carry out data analysis using software and programming language.
3. To teach a wide range of statistical skills, including problem-solving, project work and presentation so as enable students to take prominent roles in a wide spectrum of employment and research.

Programme Outcomes (PCOs):

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

1. Gain sound knowledge in theoretical and practical aspects of Statistics.
2. Describe complex statistical ideas to non-statisticians.
3. Handle and analyse large databases with computer skills and use their results and interpretations to make practical suggestions for improvement.
4. Get wide range of job opportunities in industry as well as in government sector.

III. M.A./M.Sc. Statistics Programme Details:

Programme Structure:

M.A./M.Sc. Statistics programme is a two-year course divided into four-semester. A student is required to complete **84** credits for the completion of course and the award of degree.

		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 Course**			**Open Elective Course**			**Total Credits**
	No. of Papers	Credits (L+T+P)	**Total Credits**	No. of Papers	Credits (L+T+P)	**Total Credits**	No. of Papers	Credits (L+T+P)	**Total Credits**	
I	5	16+0+4	**20**							**20**
II	5	16+0+4	**20**							**20**
III	4	12+0+4	**16**	1	3+0+1	**4**	1	*	**4**	**24**
IV	3	8+0+4	**12**	2	6+0+2	**8**				**20**
Total Credits for the Courses			**68**			**12**			**4**	**84**

***** Details are given in the list of open elective courses.

Semester wise Details:

Semester –I					
Number of Core Courses: 5					
Course code	**Course Title**	**Credits in each core course**			
		Theory	Practical	Tutorial	Credits
MSTC 101	Analysis	4	0	0	4
MSTC 102	Probability Theory	4	0	0	4
MSTC 103	Statistical Methodology	4	0	0	4
MSTC 104	Survey Sampling	4	0	0	4
MSTP 105	Practical –I	0	4	0	4
Total credits in core courses		**16**	**4**	**0**	**20**
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 electives: 0					
Total credits in open elective courses		0	0	0	**0**
Total credits in Semester –I		**16**	**4**	**0**	**20**

Semester –II

Number of Core courses: 5					
Course code	**Course Title**	**Credits in each core course**			
		Theory	Practical	Tutorial	Credits
MSTC 201	Linear Algebra	4	0	0	4
MSTC 202	Stochastic Processes	4	0	0	4
MSTC 203	Statistical Inference-I	4	0	0	4
MSTC 204	Design of Experiments	4	0	0	4
MSTP 205	Practical –II	0	4	0	4
Total credits in core courses		**16**	**4**	**0**	**20**
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 electives: 0					
Total credits in open elective courses		0	0	0	**0**
Total credits in Semester –II		**16**	**4**	**0**	**20**

Semester -III

Number of Core courses: 4					
Course code	**Course Title**	**Credits in each core course**			
		Theory	Practical	Tutorial	Credits
MSTC 301	Statistical Inference-II	4	0	0	4
MSTC 302	Multivariate Analysis	4	0	0	4
MSTC 303	Generalized Linear Model	4	0	0	4
MSTP 305	Practical –III	0	4	0	4
Total credits in core courses		**12**	**4**	**0**	**16**
Number of elective courses: 1					
		Theory	Practical	Tutorial	Credits
Elective Course 1		3	1	0	4
Total credits in elective courses		**3**	**1**	**0**	**4**
Number of open electives: 1					
Total credits in open elective courses		*	*	0	**4**
Total credits in Semester –III		**15 + ***	**5 + ***	**0**	**24**

*Details are given in the list of open elective courses.

Semester –IV

Number of Core courses: 3					
Course code	**Course Title**	**Credits in each core course**			
		Theory	Practical	Tutorial	Credits
MSTC 401	Econometrics and Time Series Analysis	4	0	0	4
MSTC 402	Demography, Statistical Quality Control and Reliability	4	0	0	4
MSTP 405	Practical –IV	0	4	0	4
Total credits in each course		**8**	**4**	**0**	**12**
Number of elective courses: 2					
		Theory	Practical	Tutorial	Credits
Elective Course 2		3	1	0	4
Elective Course 3		3	1	0	4
Total credits in elective courses		**6**	**2**	**0**	**8**
Number of open electives: 0					
Total credits in open elective courses		0	0	0	**0**
Total credits in Semester –IV		**14**	**6**	**0**	**20**

List of Elective for Semester-III

Elective Course 1: One optional paper out of the following:		
Course Code: MSTE 304	**Course Title**	**L-T-P**
MSTE 304 (i)	Bio-statistics	3-0-1
MSTE 304 (ii)	Operational Research	3-0-1
MSTE 304 (iii)	Non- Parametric Inference	3-0-1
MSTE 304 (iv)	Financial Statistics	3-0-1

List of Elective for Semester-IV

Elective Course II and Elective Course III: Two optional papers out of the following		
Course Code : MSTE 403-404	**Course Title**	**L-T-P**
MSTE 403 - 404 (i)	Applied stochastic Processes	3-0-1
MSTE 403 - 404 (ii)	Order statistics	3-0-1
MSTE 403 - 404 (iii)	Bayesian inference	3-0-1
MSTE 403 - 404 (iv)	Advanced survey sampling theory	3-0-1

MSTE 403 - 404 (v)	Advanced theory of experimental Designs	3-0-1
MSTE 403 - 404 (vi)	Advanced statistical computing and data mining	3-0-1

List of Open Elective Courses

Any one course out of the following		
Course Code : MSTOE 306	**Course Title**	**L-T-P**
MSTOE 306 (i)	Data Analysis Using R	2-0-2
MSTOE 306 (ii)	Computational Techniques	2-0-2
MSTOE 306 (iii)	Essentials of Survey Sampling and Experimental Designs	3-0-1
MSTOE 306 (iv)	Actuarial Statistics	3-0-1
MSTOE 306 (v)	Inferential Techniques	3-0-1
MSTOE 306 (vi)	Statistics for Research and Management Studies	2-0-2
XXXXX	Open Elective from other Departments	X-X-X

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. .

Teaching:

The faculty of the Department is primarily responsible for organizing lecture work M.A./M.Sc. Statistics. The instructions related to tutorials are provided by the respective registering units under the overall guidance of the Department. Faculty from some other Departments and constituent colleges are also associated with lecture and tutorial work in the Department.
There shall be 90 instructional days excluding examination in a semester.

Eligibility for Admissions:

Admission to Post-Graduate Courses in Statistics leading to a Master's Degree in Statistics will be made through two modes:

Mode-I : Direct Admission

Mode-II : Through an Entrance Test

Mode-I: 50% seats in the M.A./M.Sc. Statistics shall be filled on the basis of a merit list drawn from the category of candidates who have passed B.Sc. (Hons.) Examination in Statistics of University of Delhi under 10+2+3 scheme of examination with at least 60% marks in aggregate or equivalent CGPA.

Mode-II: The remaining 50% seats will be filled on the basis of merit in an entrance examination from the candidates satisfying any of the following eligibility criteria:

1. Any candidate who has obtained bachelor's degree in any subject and has studied at least 3 courses each of one year duration or 6 courses each of one semester duration in Statistics under 10+2+3 scheme of examination securing at least 50% marks in aggregate or equivalent CGPA will be eligible to appear in entrance examination.
2. Any candidate who has obtained bachelor's degree in Mathematics (Hons.) or Computer Science (Hons.) with at least one paper in Statistics under 10+2+3 scheme of examination of the University of Delhi or any other examination recognized as equivalent thereto with at least 50% marks in aggregate and at least 60% marks or equivalent CGPA in a paper of Statistics.

Any candidate appearing in the final year examination of bachelor's degree of the same calendar year shall also be eligible to appear in the entrance test, however, he/she will be considered for admission if he/she fulfills the other requirements of admission.

Note: If a candidate qualifies for admission through both Modes, he/she will be granted admission through Mode-I.

Number of Seats Available : 93

General Category	Mode-I	24		● Supernumerary Seats		
	Mode-II	23		PWD	Mode-I	02
SC Category	Mode-I	07			Mode-II	01
	Mode-II	07		Sports/ECA	Mode-I	Upto 03 (upto 5%)
ST Category	Mode-I	03			Mode-II	Upto 02 (upto 5%)
	Mode-II	04		CW	Mode-I	03
OBC Category	Mode-I	13			Mode-II	02
	Mode-II	12				
	Total	**93**				

● Foreign Nationals = 05 (As per the University of Delhi rules).

Modalities:

1. The candidates belonging to reserved categories will be provided relaxations/ reservations as per University rules in both the Modes of admission. It may be noted that candidates can apply simultaneously under GEN/SC/ST/OBC/PwD/Sports/ECA/CW categories.

2. Under mode-I, the minimum requirement for candidates belonging to SC/ST categories will be 40% marks in aggregate or equivalent CGPA and for OBC category will be 54% marks in aggregate or equivalent CGPA in B.Sc. (Hons.) examination in Statistics of University of Delhi.

3. Under Mode-II, the minimum requirement for candidates belonging to SC/ST categories will be 40% marks in aggregate or equivalent CGPA in the qualifying examination and for OBC category will be 45% marks in aggregate or equivalent CGPA in the qualifying examination.

4. There will be objective type question paper for entrance examination. The duration of examination, number of questions and other information regarding entrance examination will be as per the admission information bulletin of university of Delhi.

Assessment of Students' Performance and Scheme of Examinations:

(i) English shall be the medium of instruction and examination.

(ii) Examinations shall be conducted at the end of each Semester as per the Academic Calendar notified by the University of Delhi.

(iii) Examination/Evaluation: A student will be evaluated out of 2100 marks during the course.

(iv) There will be four theory papers and one practical paper in each semester. In addition, there will be one open elective paper in semester III. Each theory paper will be examined out of 100 marks (30 for internal assessment and 70 for final examination at the end of each semester). Each practical paper will be examined out of 100 marks. The practical paper in each semester consists of two parts (A and B) with the following subdivision of 50 marks for each part: Written 30 marks, Oral 10 marks, Record Book 10 marks. Examination in respect of each part will be of 2 hours duration.

SCHEME OF EXAMINATION:

First Year: Semester I (July to December)

		Duration (hrs.)	Max. Marks	Credits L+P
MSTC 101:	Analysis	3	70	4+0
MSTC 102:	Probability Theory	3	70	4+0
MSTC 103:	Statistical Methodology	3	70	4+0
MSTC 104:	Survey Sampling	3	70	4+0
MSTP 105:	Practical-I	4	100	0+4
	comprising the following two parts: **Part A:** Statistical Computing-I **Part B:** Data Analysis-I			
	Internal Assessment- I		120	
	Total		500	20

First Year: Semester II (January to May)

		Duration (hrs.)	Max. Marks	Credits L+P
MSTC 201:	Linear Algebra	3	70	4+0
MSTC 202:	Stochastic Processes	3	70	4+0
MSTC 203:	Statistical Inference-I	3	70	4+0
MSTC 204:	Design of Experiments	3	70	4+0
MSTP 205:	Practical-II	4	100	0+4
	comprising the following two parts: **Part A:** Problem Solving Using C Language **Part B:** Data Analysis-II			
	Internal Assessment- II		120	
	Total		500	20

Second Year: Semester III (July to December)

		Duration (hrs.)	Max. Marks	Credits L+P
MSTC 301:	Statistical Inference-II	3	70	4+0
MSTC 302:	Multivariate Analysis	3	70	4+0
MSTC 303:	Generalized Linear Models	3	70	4+0
MSTE 304:	Any one of the following options: (i) Bio-Statistics (ii) Operational Research (iii) Nonparametric Inference (iv) Financial Statistics	3	70	3+1
MSTP 305:	Practical-III	4	100	0+4
	comprising the following two parts: **Part A:** Statistical Computing - II (based on papers 301, 302 and 303) **Part B:** Problem Solving Using SPSS-I (based on papers 301, 302 and 303)			
MSTOE 306:	Any one of the following options: (i) Data Analysis Using R (ii) Computational Techniques (iii) Essentials of Survey Sampling and Experimental Designs (iv) Actuarial Statistics (v) Inferential Techniques (vi) Statistics for Research and Management Studies	3	70	4*
	Internal Assessment- III		150	
	Total		600	24

* Details are given in the list of open elective courses.

Second Year: Semester IV (January to May)

		Duration (hrs.)	Max. Marks	Credits L+P
MSTC 401:	Econometrics and Time Series Analysis	3	70	4+0
MSTC 402:	Demography, Statistical Quality Control and Reliability	3	70	4+0
MSTE 403-404:	Any two of the following options:	3	70	3+1
	(i) Applied Stochastic Processes	3	70	3+1
	(ii) Order Statistics (iii) Bayesian Inference (iv) Advanced Survey Sampling Theory (v) Advanced Theory of Experimental Designs (vi) Advanced Statistical Computing and Data Mining			
MSTP 405:	Practical-IV	4	100	0+4
	comprising the following two parts: **Part A:** Problem Solving Using R Software (based on papers 401 and 402) **Part B:** Problem Solving Using SPSS-II (based on papers 401 and 402)			
	Internal Assessment- IV		120	
	Total		500	20

Grand total of marks of Semester I, Semester II, Semester III and Semester IV **= 2100**

Grand total of credits of Semester I, Semester II, Semester III and Semester IV = **84**

Note 1: Each paper will carry 100 marks including 30 marks earmarked for Internal Assessment.**

Note 2: It is recommended that four lectures per week will be devoted to each of papers 101 to 104, 201 to 204, 301 to 303 and 401 to 402 and optional papers 304, 403 and 404 comprised three theory lectures and two practical hours per week. It is further recommended that each part of practical papers 105, 205, 305 and 405 will be assigned 4 periods per week.

Note 3: Each of the papers 105, 205, 305 and 405 consists of two parts (A and B) with the following subdivision of 50 marks for each part: Written 30 marks, Oral 10 marks, Record Book 10 marks. Examination in respect of each part will be of 2 hours duration.

Note 4: For open elective papers, marks for theory and practical components will depend upon the credits given to the corresponding components.

Guidelines for the Award of Internal Assessment Marks M.A./M.Sc. Statistics Programme (Semester Wise)

**** Internal Assessment for M.A./M. Sc. (Semesters I to IV)**

Internal Assessment-I : Consists in evaluation of students in papers 101 to 104 in the course of Semester I, each paper being assigned 30 marks.

Internal Assessment-II : Consists in evaluation of students in papers 201 to 204 in the course of Semester II, each paper being assigned 30 marks.

Internal Assessment-III : Consists in evaluation of students in papers 301 to 304 and 306 in the course of Semester III, each paper being assigned 30 marks.

Internal Assessment-IV : Consists in evaluation of students in papers 401 to 404 in the course of Semester IV, each paper being assigned 30 marks.

The format and modus operandi for the above Internal Assessments will be decided and announced by the Department at the beginning of a semester.

Pass Percentage, Promotion Criteria:

PASS PERCENTAGE:

Minimum marks for passing the examination in each semester shall be 40% in each paper and 45% in aggregate of a semester.

However, a candidate who has secured the minimum marks to pass in each paper but has not secured the minimum marks to pass in aggregate may reappear in any of the paper/s of his choice in the concerned semester in order to be able to secure the minimum marks prescribed to pass the semester in aggregate.

Note: Examination for courses shall be conducted only in the respective odd and even semesters as per the Scheme of Examinations. Regular as well as Ex-Students shall be permitted to appear/reappear/ improve in courses of odd semesters only at the end of odd semesters and courses of even semesters only at the end of even semesters.

No student would be allowed to avail of more than 3 chances to pass any paper inclusive of the first attempt.

PROMOTION CRITERIA:

A: **Semester to Semester:** Students shall be required to fulfill the promotion criteria from the first year to the second year of the Course. Within the same year, students shall be allowed to be promoted from a semester to the next semester, provided he/she has passed at least half the papers of the current semester.

B: **First year to Second year:** Admission to the second year of the M.A./M. Sc. Course shall be open to only those students who have successfully passed at least 75% papers out of the papers offered for the first year of the M.A./M. Sc. Course comprising Semester I and Semester II taken together. However, he/she will have to clear the remaining papers while studying in the second year of the M.A. / M. Sc. Course.

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.

Conversion of Marks into Grades:
(Specify the formula for conversion of marks into grades)

Grade Points:
Grade point table as per University Examination rule

CGPA Calculation:
As per University Examination rule.

SGPA Calculation:
As per University Examination rule.

Grand SGPA Calculation:
As per University Examination rule.

Conversion of Grand CGPA into Marks:
As notified by competent authority the formula for conversion of Grand CGPA into marks is:
Final %age of marks = CGPA based on all four semesters × 9.5

Division of Degree into Classes:
Post Graduate degree to be classified based on CGPA obtained into various classes as notified into Examination policy.

Attendance Requirement:
50% attendance is required to appear in for the mid-term examination and 66% attendance is required to appear in the End Semester Examination.

IV: Course Wise Content Details for MASTER OF STATISTICS

M.A./ M.Sc. (Statistics) Programme

Semester- I

MSTC 101: Analysis

Course Objectives: The main objective of this course is to introduce students the knowledge of real field and complex field with their properties and relativity between complex plane and real line. These properties and relations provides grounds for Probability Theory and help in theoretical research in Statistics.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Understand existence of integral and their evaluation.
2. Understand convergence of sequence and series of real valued function and complex valued functions.
3. Understand change of multiple integral into line integral.
4. Find maxima-minima of functions of several variables.
5. Understand complex region and relativity between complex plane and real line.
6. To solve contour integrals.
7. Find residue at singularity and infinity via definition and via Cauchy integral formula.

Unit I: Functions of bounded variation, Riemann integration and Riemann-Stieltjes integration, Statement of the standard property and problem based on them, Multiple integrals, repeated integrals, Change of variables in multiple integration.

Unit II: Differentiation under integral sign, Leibnitz rule, Dirichlet integral, Liouville's extension, Uniform convergence of sequence of functions and series of functions, Cauchy's criteria and Weirstrass M-test, Maxima-minima of functions of several variables, Constrained maxima-minima of functions.

Unit III: Properties of complex numbers, Region in complex plane, Limit, continuity and differentiability of function of complex variables, Analytic function, Contour integration, Cauchy integral formula, Liouville's theorem, Fundamental theorem of Algebra.

Unit IV: Power series and radius of convergence, Taylor's and Laurent's series, Singular points and their types, Residue at singular point and residue at infinity, Cauchy residue theorem, Evaluation of real integrals involving sine and cosine using residue.

Suggested Readings:

1. Brown, J. W. and Chirchill, R. V. (2009). Complex variables and Applications, McGraw Hill.
2. Bartle, R. G. (1976). Elements of Analysis, John Wiley & Sons.
3. Bak, J. and Newman, D. J. (1997). Complex Analysis, Springer.
4. Rudin, W. (1985). Principles of Mathematical Analysis, McGraw Hill.
5. Rose, K. A. (2004). Elementary Analysis: The Theory of Calculus, Springer (SIE).

Teaching Plan:

Week 1: Functions of bounded variations. Total variation. Positive variation and negative variation. Expression of a function of bounded variation in terms of monotonically increasing functions.

Week 2-3 : Riemann integration. Inequalities of upper and lower sums. Riemann conditions of integrability. Riemann sum and definition of Riemann integral through Riemann sums. Riemann integrability of continuous functions. Monotonic functions and functions with finite number of discontinuities.

Week 4: Intermediate value theorem for integrals. Fundamental theorem of Calculus. Riemann-Stieltjes integral. Evaluating Riemann-Stieltjes integral using definition and also by reducing it to Riemann integral.

Week 5: Multiple integrals and their evaluation by repeated integration. Change of variable in multiple integration. Differentiation under integral sign. Leibnitz rule. Dirichlet integral. Liouville's extension.

Week 6: Pointwise and uniform convergence of sequence of functions. Cauchy's criteria and Weirstrass M-test. Continuity, differentiability and integrability of a limit function.

Week 7: Uniform convergence of series of functions. Conditions for continuity, differentiability and integrability of the sum function. Maxima-minima of functions of several variables. Constrained maxima-minima of functions.

Week 8- 9: Properties of complex numbers. Region in the complex plane. Functions of complex variable. Limit, continuity and differentiability of functions of complex variable. Cauchy Riemann equations. Sufficient conditions for differentiability. Analytic functions and examples of analytic functions.

Week 10: Contour integrals and its example. Upper bounds for moduli of contour integrals. M-L formula. Antiderivatives. Cauchy theorem. Cauchy-Goursat theorem and Cauchy integral formula.

Week 11: Liouville's theorem and fundamental theorem of Algebra. Convergence of sequence and series. Absolute and uniform convergence of power series.

Week 12: Taylor's series and Laurent's series and their examples. Uniqueness of series representation of power series.

Week 13: Singular points. Classification of singularity. Residue at poles and its examples. Residue at infinity with examples.

Week 14: Cauchy residue theorem. Evaluation of definite integrals and real integrals involving sine and cosines.

MSTC 102: Probability Theory

Course Objectives: The aim of the course is to pay a special attention to applications of measure theory in the probability theory, understanding of Weak Law of Large Numbers, Strong Law of Large Numbers and the Central Limit Theorem with their applications.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Understand the concepts of random variables, sigma-fields generated by random variables, probability distributions and independence of random variables related to measurable functions.
2. Gain the ability to understand the concepts of measurable functions, sequence of random variables, convergence, modes of convergence.
3. Learn the concepts of weak and strong laws of large numbers and central limit theorem.

Unit I: Classes of sets, fields, σ -fields, minimal σ -field, Borel σ – field in R^K , sequence of sets, limsup and liminf of a sequence of sets. Measure, Probability measure, properties of a measure, Caratheodory extension theorem (statement only), Lebesgue and Lebesgue-Stieltjes measures on R^K

Unit II: Measurable functions, Random variables, sequence of random variables, almost sure convergence, convergence in probability, in the rth mean and in distribution, their relationship. Integration of a measurable function with respect to a measure. Helly-Bray theorem Monotone convergence theorem, Fatou's lemma, Dominated convergence theorem, three series criterion. Characteristic functions, uniqueness/inversion/Levy continuity theorems.

Unit III: Markov's, Chebychev's and Kolmogorov's inequalities, Modes of stochastic convergence, Jenson, Liapounov, holder's and Minkowsky's inequalities, Sequence of random variables and modes of convergence (convergence in distribution, in probability, almost surely, and quadratic mean) and their interrelations. Statement of Slutsky's theorem, Borel –Cantelli lemma and Borel 0-1 law.

Unit IV: Concept of Independence, Laws of large numbers, Chebyshev's and Khinchine's WLLN, necessary and sufficient condition for the WLLN, strong law of large numbers and Kolmogorov's theorem, Central limit theorem, Lindeberg and Levy and Liapunov forms of CLT, Definition and examples of Markov dependence, exchangeable sequences, m-dependent sequences, stationary sequences, martingales.

Suggested readings:

1. Ash, R. B. and Doléans-Dade, C.A. (1999). Probability and Measure Theory, Second Edition, Academic Press, New York.
2. Billingsley, P. (2012). Probability and Measure, Anniversery Edition, John Wiley & Sons.
3. Bhat, B.R. (1999). Modern Probability Theory, 3rd Edition, New Age International Publishers.
4. Capinski, M. and Zastawniah (2001). Probability through problems, Springer.
5. Chung, K. L. (1974). A Course in Probability Theory, 2nd Edition, Academic Press, New York.
6. Feller, W. (1968). An Introduction to Probability Theory and its Applications, Vol. 1, 3rd Edition, John Wiley & Sons.
7. Parzen, E. (1960). Modern Probability Theory and its Application. Wiley Eastern Private Ltd.

Teaching Plan:

Week 1: Classes of sets, fields, σ -fields, minimal σ -field, Borel σ – field in R^K, sequence of sets, limsup and liminf of a sequence of sets.

Week 2 : Measure, Probability measure, properties of a measure, Caratheodory extension theorem (statement only), Lebesgue and Lebesgue-Stieltjes measures on R^K.

Week 3: Measurable functions, Random variables, sequence of random variables, almost sure convergence, convergence in probability, in the r^{th} mean and in distribution, their relationship.

Week 4: Integration of a measurable function with respect to a measure. Helly-Bray theorem Monotone convergence theorem.

Week 5: Fatou's lemma, Dominated convergence theorem, three series criterion.

Week 6: Characteristic functions, uniqueness/inversion/Levy continuity theorems.

Week 7: Markov's, Chebychev's and Kolmogorov's inequalities. Modes of stochastic convergence. Jensen, Liapunov, Holder's and Minkowsky's inequalities.

Week 8: Sequence of random variables and modes of convergence (convergence in distribution, in probability, almost surely, and quadratic mean) and their interrelations.

Week 9: Statement of Slutsky's theorem. Borel –Cantelli lemma and Borel 0-1 law.

Week 10: Concept of Independence, Laws of large numbers, Chebyshev's and Khinchine's WLLN, necessary and sufficient condition for the WLLN.

Week 11: Strong law of large numbers and Kolmogorov's theorem.

Week 12: Central limit theorem, Lindeberg and Levy and Liapunov forms of CLT.

Week 13: Definition and examples of Markov dependence, exchangeable sequences, m-dependent sequences, stationary sequences.

Week 14: Martingales.

MSTC 103: Statistical Methodology

Course Objective: The aim of this course is to provide a thorough theoretical grounding in different type of distributions, non-central distributions, censoring, delta method, robust procedures etc.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Formulate the mathematical/statistical models for real data sets arising in various fields in order to analyse in respect of various useful characteristics of the populations.
2. Understand how to use non-central distributions in real life problems.
3. Understand different types of censoring schemes.
4. Work with incomplete data which is a challenging problem in today's life.

Unit I: Brief review of basic distribution theory, Symmetric distributions, Truncated distributions, Compound distributions, Mixture of distributions, Generalized power series distributions, Exponential family of distributions.

Unit II: Characterization of distributions (Geometric, negative exponential, normal, gamma), Non-central Chi-square, t and F distributions and their properties, Concept of censoring. Approximating distributions, Delta method and its applications, Approximating distributions of sample moments, Limiting moment generating function, Poisson approximation to negative binomial distribution.

Unit III: Order statistics-their distributions and properties. Joint and marginal distributions of order statistics. Extreme values and their asymptotic distributions (statement only) with applications. Tolerance intervals, coverage of $(X_{(r)}, X_{(s)})$. General theory of regression, fitting of polynomial regression by orthogonal methods, multiple regression, examination of regression equation.

Unit IV: Robust procedures, Robustness of sample mean, Sample standard deviation, Chi-square test and Student's t-test. Sample size determination for testing and estimation procedures (complete and censored data) for normal, exponential, Weibull and gamma distributions.

Suggested Readings:

1. Arnold, B.C., Balakrishnan, N., and Nagaraja, H.N. (1992). A First Course in Order Statistics, John Wiley & Sons.
2. Biswas, S. (1992). Topics in Statistical Methodology, Wiley-Blackwell.
3. David, H.A., and Nagaraja, H.N. (2003). Order Statistics, 3rd Edn., John Wiley & Sons.
4. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics, Wiley, International Students' Edition.
5. Huber, P.J. (1981). Robust Statistics, John Wiley & Sons.
6. Johnson, N.L., Kotz, S. and Balakrishnan, N. (2000). Discrete Univariate John Wiley & Sons.
7. Johnson, N.L., Kotz, S. and Balakrishnan, N. (2000). Continuous Univariate Distributions, John Wiley & Sons.
8. Mukhopadhyay, P. (2015). Mathematical Statistics. New Central Book Agency.
9. Rohatgi, V.K. and Saleh, A. K. Md. E. (2005). An Introduction to Probability and Statistics, 2nd Edn., John Wiley & Sons.
10. Rohatgi, V.K. (1984). Statistical Inference, John Wiley & Sons.
11. Rao, C.R. (1973). Linear Statistical Inference and Its Applications, 2nd Edn., John Wiley & Sons.

Teaching Plan:

Week 1: Concept of sample space, random variable, sigma field, minimal sigma field, probability measure, properties of probability density functions/probability mass functions and cumulative distribution functions, Concept of symmetric distributions.

Week 2 : Examples of discrete and continuous symmetric distributions, theorems based on symmetric distributions, Concept of truncated distributions, Examples of discrete and continuous truncated distributions, Concept of compound distributions, Examples of compound distributions.

Week 3: Concept of generalized power series distribution, moment generating function, Recurrence relation and cumulents of generalized power series distribution, Particular cases of generalized power series distribution.

Week 4: Brief discussion of one parameter, two parameter and k-parameters exponential family of distributions. Particular cases of exponential family of distributions, Maximum likelihood estimation of exponential family of distributions and theorems based on exponential family of distributions.

Week 5: Characterization properties and theorem of geometric distribution, Characterization properties of exponential distribution and related theorems, Characterization properties of normal distribution and related theorems. Characterization properties of gamma distribution.

Week 6: Brief discussion of central Chi-square. Concept of Non-central Chi-square distribution, derivation of the probability density functions, characteristic functions, moment generating function, Cumulants and other theorems based on Non-central Chi-square distribution.

Week 7: Brief discussion of t and F distributions. Concept of Non-central t and F distributions, derivation of their probability density functions, Derivation of r^{th} moment about origins of non-central t and F distributions. Derivation of mean and variance of non-central t and F distributions.

Week 8-9: Discussion of Type I censoring, Type II censoring and Progressive censoring and problems based on these censoring schemes, Concept of Approximating distributions, First order, second order and higher order delta method. Problems based on delta method.

Week 10: Approximating distributions of sample moments, Limiting moment generating function, Poisson approximation to negative binomial distribution, Concept of order statistics and problems/theorems based on order statistics.

Week 11: Concept of tolerance intervals and problems based on tolerance intervals, Coverage of $(X_{(r)}, X_{(s)})$, General theory of linear and multiple regression.

Week 12: Fitting of polynomial regression by orthogonal methods, multiple regression, and examination of regression equation.

Week 13: Concept of Robust procedures, Robustness of sample mean, Sample standard deviation, Chi-square test and Student's t-test.

Week 14: Sample size determination for testing and estimation procedures (complete and censored data) for normal, exponential, Weibull and gamma distributions.

MSTC 104: Survey Sampling

Course Objectives: The main objective of this course is to learn techniques in survey sampling with practical applications in daily life which would be beneficial for the students to their further research.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Understand the distinctive features of sampling schemes and its related estimation problems
2. Learn about various approaches (design based and model-based) to estimate admissible parameters; with and without replacement sampling scheme, sampling with varying probability of selection.
3. Learn about the methods of post–stratification (stratified sampling) and controlled sampling and also double sampling procedure with unequal probability of selection.
4. Learn about the applications of sampling methods; systematic, stratified and cluster sampling.
5. Understand the cluster and two stage sampling with varying sizes of clusters/first stage units.
6. Understand the super population approach to estimation.
7. Learn about the randomized response techniques.

Unit I: Basic ideas and distinctive features of sampling, Probability sampling designs, sampling schemes, inclusion probabilities and estimation. Review of important results in simple and stratified random sampling, Fixed (Design –based) and Superpopulation (model-based) approaches. Non-sampling errors with special reference to non-response.

Unit II: Sampling with varying probabilities (unequal probability sampling) with or without replacement: pps, πps and non- πps sampling procedures and estimation based on them, Non-negative variance estimation.

Unit III: Two-way stratification, post-stratification, controlled sampling, Estimation based on auxiliary data (involving one or more auxiliary variables) under design-based and model-based approaches, Double (two-phase) sampling with special reference to the selection with unequal probabilities in at least one of the phases.

Unit IV: Systematic sampling and its application to structured populations, Cluster sampling (with varying sizes of clusters), Two-stage sampling (with varying sizes of first-stage units), Warner's and Simmons' randomized response techniques for one qualitative sensitive characteristic.

Suggested Readings:

1. Chaudhari, A. and Stenger, H. (2005). Survey Sampling Theory and methods, 2nd Edn., Chapman and Hall.
2. Chaudhari, A. and Vos, J.W.E. (1988). Unified Theory and Strategies of Survey Sampling, North –Holland, Amsterdam.
3. Cassel, C.M., Sarndal, C-E and Wretman, J.H. (1977). Foundations of Inference in Survey Sampling, Wiley Inter-Science, New York.
4. Cochran, W.G. (1977). Sampling Techniques, John Wiley & Sons, New York.
5. Hedayat, A.S., and Sinha, B.K. (1991). Design and Inference in Finite Population Sampling, Wiley, New York.
6. Levy, P.S. and Lemeshow, S. (2008). Sampling of Populations-Methods and Applications, Wiley, New York.
7. Murthy, M.N. (1967). Sampling Theory and Methods, Statistical Publishing Society, Calcutta.
8. Raj, D. and Chandhok, P. (1998). Sample Survey Theory, Narosa Publishing House.
9. Mukhopadhyay, P. (2009). Theory and Methods of Survey Sampling, 2nd Edn., Prentice Hall of India, New Delhi.
10. Sarndal, C.E., Swensson, B. and Wretman, J.H. (1992). Model Assisted Survey Sampling, Springer-Verlag, New York.
11. Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984). Sampling Theory of Surveys with Applications, Iowa State University Press, Iowa, USA.
12. Thompson, S. K. (2002). Sampling, John Wiley & Sons, New York.

Teaching Plan:

Week 1: Basic ideas and distinctive features of sampling; Probability sampling designs, sampling schemes, inclusion probabilities and estimation.

Week 2-3: Review of important results in simple and stratified random sampling, Fixed (Design – based) and Superpopulation (model- based) approaches.

Week 4: Non-sampling errors with special reference to non-response.

Week 5-6: Sampling with varying probabilities (unequal probability sampling) with or without replacement

Week 7: pps, πps and non-πps sampling procedures and estimation based on them; Non-negative variance estimation

Week 8-9: Two-way stratification, post-stratification, controlled sampling. Estimation based on auxiliary data (involving one or more auxiliary variables) under design-based and model- based approaches.

Week 10: Double (two-phase) sampling with special reference to the selection with unequal probabilities in at least one of the phases.

Week 11: Systematic sampling and its application to structured population.

Week 12: Cluster sampling (with varying sizes of clusters).

Week 13: Two-stage sampling (with varying sizes of first-stage units).

Week 14: Warner's and Simmons' randomized response techniques for one qualitative sensitive characteristic.

MSTP 105: Practical-I

Part-A (Statistical Computing-I)

Review of programming in C: Operators & expressions; Flow control; Functions; Arrays; Strings; Pointers; Structures.

Computer representation of numbers, Errors. Bitwise operations. The C Preprocessor, Macros.

Linked Lists; Stacks & Queues. Sorting – Introduction, bubble sort, selection sort, insertion sort, quick sort.

Random numbers: Pseudo-Random number generation, tests. Random variable generation, Inverse-Transform method, Composition Method, Acceptance-Rejection Method. Generating discrete and continuous random variables. Simulation- Random Walk. Applications relating to the problems based on other courses viz., Probability Theory, Statistical Methodology, Survey Sampling.

Suggested Readings:

1. Gottfried, B.S. and Chhabra, J.K. (2006). Programming with C, Tata McGraw Hill Publishing Co. Ltd., New Delhi (SIE).
2. Knuth, D.E. (2002). The Art of Computer Programming, Vol. 2/Semi numerical Algorithms, Pearson Education (Asia).
3. Kernighan, B.W. and Ritchie, Dennis M. (1989). The C Programming Language, Prentice Hall of India Pvt. Ltd., New Delhi.
4. Rubinstein, R.Y. (2017). Simulation and the Monte Carlo Method, 3rd ed., John Wiley & Sons.
5. Ross, S.M. (2012). Simulation, 5th ed., Academic press.
6. Thareja, R. (2014). Data Structures using C, Oxford University Press, New Delhi, India.

Part B: Data Analysis-I

Computer-based data analysis of problems.

List of Practicals:

1. Study of convergence of sequence through plotting.
2. Study the convergence/divergence of infinite series by plotting their sequences of partial sum.
3. Evaluating line integral and multiple integral.
4. Program to discuss the algebra of complex numbers.

5. To perform contour integration.
6. To plot the complex functions and analyse the graph.
7. To perform Taylor series and Laurent's series expansion of a given function f(z) around a given point z.
8. To compute poles and corresponding residue of complex function of sets.
9. To examine whether a given function is measurable or not.
10. To find out Lebesgue- Stieltjes measure of a given real valued function of a real variable.
11. To find out marginal distribution function of random variables X and Y when some distribution function f(X,Y) is given.
12. To check a sequence of set for convergence and to find out limit of the sequence if exists.
13. To find the limit inferior and limit superior of a given sequence of sets.
14. To check whether a given sequence of random variables $\{X_n\}$ is uniformly integrable or not.
15. For a sequence of random variables check whether $E (\lim X_n) = \lim E(X_n)$ holds or not.
16. Problems based on censoring.
17. Problems based on maximum likelihood estimation.
18. Problems based on tolerance intervals.
19. Random number generation from non-central Chi square distribution.
20. Random number generation from non-central t-distribution.
21. Random number generation from non-central F-distribution.
22. Problems based on sample size determination for testing.
23. To select simple random Sample with and without replacement and estimate population mean and population variance for a given sample size.
24. To select Stratified Random Sample for a given population.
25. Allocation of sample using proportional and Neyman method of allocation and comparing their efficiencies relative to SRS.
26. Systematic Sampling.
27. To estimate population mean in case of sampling with varying probabilities of selection.
28. Cluster Sampling.
29. Two- stage Sampling.

Semester- II

MSTC 201: Linear Algebra

Course Objectives: The main objective of this paper is to allow students to manipulate and understand multidimensional space.

Course Learning Outcomes: After completing this course students will have a clear understanding of:

1. Whole system of equations with multiple dimensions/variables.
2. Importance of concept of linear algebra in multiple area of science.
3. Concepts of Generalized inverse theory and applications.
4. Concepts of Linear Transformations and inner product spaces.
5. Concepts and detailed theory of Eigen values and Eigen vectors.
6. Concepts of Quadratic equations.

Unit I: Concept of groups and fields with examples, Vector spaces and Subspaces with examples, Direct sum and Algebra of subspaces viz. sum, intersection, union etc, Linear combinations, Spanning sets, Linear spans, Linear dependence and independence in vector spaces, Row and Column space of a matrix, Basis and Dimensions.

Unit II: Linear Transformations, Kernel and Image of a linear transformation, Rank and Nullity, Matrix representation of a linear operator, Change of Basis, Similarity, Inner product spaces with examples, Cauchy-Schwarz inequality with applications, Orthogonality, Orthonormal sets and Bases, Gram Schmidt Orthogonalization Process.

Unit III: Eigenvalues and eigenvectors, Spectral decomposition of a symmetrical matrix (Full rank and non-full rank cases), Example of spectral decomposition, Spectral decomposition of asymmetric matrix, Cayley Hamilton theorem, Algebraic and geometric multiplicity of characteristic roots, Diagonalization of matrices, Factorization of a matrix, Eigenvalues and eigenvectors for solution of Differential equations.

Unit IV: Generalized inverse of a matrix, Different classes of generalized inverse, Properties of g-inverse, Reflexive g-inverse, left weak and right weak g-inverse, Moore- Penrose (MP) g-inverse and its properties, Real quadratic form, Linear transformation of quadratic forms, Index and signature, Reduction of quadratic form into sum of squares, Gram matrix with example, Jordan canonical form.

Suggested Readings:

1. Biswas, S. (1997). A Text Book of Matrix Algebra, 2nd ed., New Age International Publishers.
2. Golub, G.H. and Van Loan, C.F. (1989). Matrix Computations, 2nd ed., John Hopkins University Press, Baltimore-London.
3. Hadley, G. (2002). Linear Algebra. Narosa Publishing House (Reprint).
4. Robinson, D.J.S. (1991). A Course in Linear Algebra with Applications, World Scientific, Singapore.
5. Rao, C.R. (1973). Linear Statistical Inferences and its Applications, 2nd ed., John Wiley & Sons.
6. Searle, S.R. (1982). Matrix Algebra useful for Statistics, John Wiley & Sons.
7. Strang, G. (1980). Linear Algebra and its Application, 2nd ed., Academic Press, London New York.

Teaching Plan:

Week 1: Concept of groups and fields with examples, Vector spaces and Subspaces with examples, Direct sum of subspaces.

Week 2 : Algebra of subspaces viz. sum, intersection, union etc, Linear combinations, Spanning sets, Linear spans

Week 3: Linear dependence and independence in vector spaces, Row and Column space of a matrix, Basis and Dimensions.

Week 4: Linear Transformations, Kernel and Image of a linear transformation, Rank and Nullity.

Week 5: Matrix representation of a linear operator, Change of Basis, Similarity.

Week 6: Inner product spaces with examples, Cauchy-Schwarz inequality with applications.

Week 7: Orthogonality, Orthonormal sets and Bases, Gram Schmidt Orthogonalization Process.

Week 8: Eigenvalues and eigenvectors.

Week 9: Spectral decomposition of a symmetrical matrix (Full rank and non-full rank cases), Example of spectral decomposition, Spectral decomposition of asymmetric matrix, Cayley Hamilton theorem.

Week 10: Algebraic and geometric multiplicity of characteristic roots, Diagonalization of matrices, Factorization of a matrix, Eigenvalues and eigenvectors for solution of Differential equations

Week 11-12: Generalized inverse of a matrix, Different classes of generalized inverse, Properties of g-inverse, Reflexive g-inverse, left weak and right weak g-inverse, Moore - Penrose (MP) g-inverse and its properties.

Week 13-14: Real quadratic form, Linear transformation of quadratic forms, Index and signature, Reduction of quadratic form into sum of squares, Gram matrix with example, Jordan canonical form.

MSTC 202: 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 inventory or queueing situations or stock prices behavior.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Use notions of long-time behaviour including transience, recurrence, and equilibrium in applied situations such as branching processes and random walk.
2. Construct transition matrices for Markov dependent behaviour and summarize process information
3. Use selected statistical distributions for modeling various phenomena.
4. Understand the principles and objectives of model building based on Markov chains, Poisson processes and Brownian motion.

Unit I: Review of Basic Probability Concepts. Introduction to Stochastic Processes. Deterministic and Stochastic Exponential Growth Models. Stationary and Evolutionary Processes.

Poisson Processes: Poisson distribution and Poisson Process. Arrival, Interarrival and Conditional Arrival Distributions. Nonhomogeneous Processes. Law of Rare Events and Poisson Process. Poisson Point Process. Distributions associated with Poisson Process. Compound Poisson Processes.

Unit II: Markov Chains : Transition Probability Matrices, Chapman- Kolmogorov equations, Some Examples and Classification of States, Regular Chains and Stationary Distributions, Periodicity, Limit theorems. Fundamental Matrix. Some Applications.

Patterns for recurrent events: One-dimensional, two-dimensional and three-dimensional random walks.

Unit III: Brownian Motion: Limit of Random Walk, Its Defining Characteristics and Peculiarities. Its Variations: Standard Brownian Motion, Brownian Bridge, Brownian Motion Reflected at Origin, Geometric Brownian Motion, Brownian Motion with Drift. Reflection Principle. Some Applications.

Unit IV: Renewal Processes: Preliminaries, Elementary Renewal Theorem, Delayed Renewal Processes. Limit Theorems.

Martingales: Definitions and Some Examples, Stopping Times, Martingale Stopping Theorem, Wald Equation.

Suggested Readings:

1. Bhat, B.R. (2000). Stochastic Models- Analysis and Applications, New Age International Publishers.
2. Feller, William (1968). An Introduction to Probability Theory and its Applications, Vol. 1, 3rd Edn., John Wiley & Sons.
3. Karlin, S. and Taylor, H.M. (1975). A first course in Stochastic Processes, Second ed. Academic Press
4. Medhi, J. (1994). Stochastic Processes, Seconded Wiley Eastern Ltd.
5. Prabhu, N.U. (2007). Stochastic Processes: Basic Theory and its Applications, World Scientific
6. Ross, S. M. (1996). Stochastic Processes, John Wiley and Sons, Inc
7. Taylor, H.M. and Karlin, S. (1998). An Introduction To Stochastic Modelling, 3rd ed., Academic Press.

Teaching Plan:

Week 1: Review of basic Probability Concepts. Introduction to Stochastic Processes. Deterministic and Stochastic Exponential Growth Models. Stationary and Evolutionary Processes.

Week 2 : Poisson Processes: Poisson Distribution and Poisson Process. Arrival, Interarrival and Conditional Arrival Distributions. Nonhomogeneous Processes.

Week 3: Poisson Processes: Law of Rare Events and Poisson Process. Poisson Point Process.

Week 4: Distributions associated with Poisson Process. Compound Poisson Processes.

Week 5: Markov Chains : Transition Probability Matrices, Chapman- Kolmogorov equations, Some Examples and Classification of States

Week 6: Markov Chains : Regular Chains and Stationary Distributions, Periodicity

Week 7: Markov Chains : Limit theorems, Fundamental Matrix, Some Applications

Week 8: Patterns for recurrent events: One-dimensional, two-dimensional and three-dimensional random walks.

Week 9: Brownian Motion: Limit of Random Walk, Its Defining Characteristics and Peculiarities.

Week 10: Brownian Motion: Its Variations: Standard Brownian Motion, Brownian Bridge, Brownian Motion Reflected at Origin, Geometric Brownian Motion, Brownian Motion with Drift.

Week 11: Brownian Motion: Reflection Principle. Some Applications.

Week 12: Renewal Processes: Preliminaries, Elementary Renewal Theorem, Delayed Renewal Processes.

Week 13: Renewal Processes: Limit Theorems. Martingales: Definitions and some examples.

Week 14: Stopping Times, Martingale Stopping Theorem, Wald Equation.

MSTC 203: Statistical Inference-I

Course Objectives: To make students aware of estimation (point, as well as, interval) and 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 estimation and testing procedures to deal with real life problems.
2. Understand Fisher Information, Lower bounds to variance of estimators, MVUE.
3. Understand Neyman-Pearson fundamental lemma, UMP test, Interval estimation and confidence interval.

Unit I: Minimal sufficiency and ancillarity, Exponential families and Pitman families, Invariance property of Sufficiency under one-one transformations of sample and parameter spaces. Fisher Information for one and several parameters models. Lower bounds to variance of estimators, necessary and sufficient conditions for MVUE.

Unit II: Neyman-Pearson fundamental lemma and its applications, UMP tests for simple null hypothesis against one-sided alternatives and for one-sided null against one-sided alternatives in one parameter exponential family. Extension of these results to Pitman family when only upper or lower end depends on the parameters and to distributions with MLR property.

Unit III: Non-existence of UMP tests for simple null against two-sided alternatives in one parameter exponential family. Families of distributions with monotone likelihood ratio and UMP tests.

Unit IV: Interval estimation, confidence level, construction of shortest expected length confidence interval, Uniformly most accurate one-sided confidence Interval and its relation to UMP tests for one-sided null against one-sided alternative hypotheses.

Suggested Readings:

1. Bartoszynski, R. and Bugaj, M.N. (2007). Probability and Statistical Inference, John Wiley & Sons.
2. Ferguson, T.S. (1967). Mathematical Statistics, Academic Press.

3. Kale, B.K. (1999). A First Course on Parametric Inference, Narosa Publishing House.
4. Lehmann, E.L. (1986). Theory of Point Estimation, John Wiley & Sons.
5. Lehmann, E.L. (1986). Testing Statistical Hypotheses, John Wiley & Sons.
6. Rohatgi, V.K. and Saleh, A.K. Md. E. (2005). An Introduction to Probability and Statistics, 2nd Edn., John Wiley & Sons.
7. Rao, C.R. (1973). Linear Statistical Inference and Its Applications, 2^{nd} ed., Wiley Eastern Ltd., New Delhi.
8. Zacks, S. (1971). Theory of Statistical Inference, John Wiley & Sons.

Teaching Plan:

Week 1-2 : Minimal sufficiency and ancillarity.

Week 3 : Exponential families and Pitman families.

Week 4: Invariance property of Sufficiency under one-one transformations of sample and parameter spaces.

Week 5: Fisher Information for one and several parameters models.

Week 6: Lower bounds to variance of estimators, necessary and sufficient conditions for MVUE.

Week 7: Neyman-Pearson fundamental lemma and its applications.

Week 8: UMP tests for simple null hypothesis against one-sided alternatives and for one-sided null against one-sided alternatives in one parameter exponential family.

Week 9: Extension of these results to Pitman family when only upper or lower end depends on the parameters and to distributions with MLR property.

Week 10: Non-existence of UMP tests for simple null against two-sided alternatives in one parameter exponential family.

Week 11: Families of distributions with monotone likelihood ratio and UMP tests.

Week 12: Interval estimation, confidence level, construction of shortest expected length confidence interval.

Week 13: Uniformly most accurate one-sided confidence Interval.

Week 14: Its relation to UMP tests for one-sided null against one-sided alternative hypotheses.

MSTC 204: Design 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 two –way classification, fixed effect models with equal, unequal and proportional number of observations per cell, Random and Mixed effect models with m (>1) observations per cell.
2. Design and analyse incomplete block designs, understand the concepts of orthogonality, connectedness and balance.
3. Understand the concepts of finite fields and finite geometries and apply them in construction of MOLS, balanced incomplete block designs, confounded factorial experiments.
4. Identify the effects of different factors and their interactions and analyse factorial experiments.
5. Construct complete and partially confounded factorial designs and perform their analysis.
6. Apply Split-plot designs and their analysis in practical situations.
7. Understand the effects of independence or dependence of different factor under study.

Unit I: Review of linear estimation and basic designs. Elimination of heterogeneity in two directions. ANOVA: Fixed effect models (2-way classification with equal, unequal and proportional number of observations per cell), Random and Mixed effect models (2-way classification with m (>1) observations per cell).

Unit II: Incomplete Block Designs. Concepts of Connectedness, Orthogonality and Balance. Intrablock analysis of General Incomplete Block design. B.I.B designs with and without recovery of interblock information.

Unit III: Finite fields. Finite Geometries- Projective geometry and Euclidean geometry. Construction of complete set of mutually orthogonal latin squares. Construction of B.I.B.D. using finite Abelian groups, MOLS, finite geometry and method of differences.

Unit IV: Symmetrical factorial experiments ($s^{m,}$ where s is a prime or a prime power), Confounding in s^m factorial experiments through pencils, s^{k-p} fractional factorial where s is a prime or a prime power. Split-plot experiments.

Suggested Readings:

1. Chakrabarti, M.C. (1962). Mathematics of Design and Analysis of Experiments, Asia Publishing House, Bombay.
2. Dean, A. and Voss, D. (1999). Design and Analysis of Experiments, Springer. First Indian Reprint 2006.
3. Das, M.N. and Giri, N.C. (1986). Design and Analysis of Experiments, Wiley Eastern Limited.
4. Dey, A. (1986). Theory of Block Designs, John Wiley & Sons.
5. Hinkelmann, K. and Kempthorne, O. (2005). Design and Analysis of Experiments, Vol. 2: Advanced Experimental Design, John Wiley & Sons.
6. John, P.W.M. (1971). Statistical Design and Analysis of Experiments, Macmillan Co., New York.
7. Kshirsagar, A.M. (1983). A Course in Linear Models, Marcel Dekker, Inc., N.Y.
8. Montgomery, D. C. (2005). Design and Analysis of Experiments, 6^{th} ed., John Wiley & Sons.
9. Raghavarao, D. and Padgett, L. V. (2005). Block Designs: Analysis, Combinatorics, and Applications, World Scientific.
10. Raghavarao, D. (1970). Construction and Combinatorial Problems in Design of Experiments, John Wiley & Sons.

Teaching Plan:

Week 1 : Review of linear estimation and basic designs, elimination of heterogeneity in two directions.

Week 2 : ANOVA, Fixed effect models (2-way classification with equal, unequal and proportional number of observations per cell).

Week 3: ANOVA,Random and Mixed effect models (2-way classification with m (>1) observations per cell).

Week 4-5: Incomplete Block Designs. Concepts of Connectedness, Orthogonality and Balancedness.

Week 6-7: Intrablock analysis of General Incomplete Block design. B.I.B designs with and without recovery of interblock information.

Week 8: Finite fields.

Week 9: Finite Geometries- Projective geometry and Euclidean geometry.

Week 10: Construction of complete set of mutually orthogonal latin squares. Construction ofB.I.B.D. using finite Abelian groups and MOLS.

Week 11: Construction of B.I.B.D using finite geometry and method of differences.

Week 12-13: Symmetrical factorial experiments (s^m, where s is a prime or a prime power), Confounding in s^m factorial experiments through Pencils.

Week 14: s^{k-p} fractional factorial where s is a prime or a prime power. Split-plot experiments.

MSTP: Practical-II

Part A: Problem Solving using C language

Part B: Data Analysis-II

Computer-based data analysis of problems.

List of Practicals:

1. Problems based on solution of system of linear equations.
2. Problems based on Cayley-Hamilton theorem.
3. Problems based on Gram-Schmidt process.
4. Verification of Spectral decomposition theorem.
5. Verification of the properties of characteristic roots.
6. Problems based on checking weather a given matrix/quadratic form is positive definite, negative definite, semi positive definite or semi negative definite.
7. Problems based on generalized inverse (g-inverse), Reflexive g-inverse, left weak and right weak g-inverse, Moore and Penrose (MP) g-inverse and verification of their properties.
8. Limiting State Probabilities.
9. Computing Mean First Passage Times.
10. Expected Duration for Gambler's Ruin.
11. Probability distribution for Growth.
12. Problems based on construction of critical region of size α and plotting the power curve for testing of hypothesis.
13. Construction of confidence interval for the parameters.
14. Construction of confidence interval for the difference and ratio of parameters.
15. Problems based on finding the UMPCR of size α.
16. Problems based on finding the length of the confidence interval.
17. ANOVA for two –way classification:
    - (i) Fixed effect model: equal, unequal and proportional number of observations.
    - (ii) Random effect model with 'm' observations per cell.
    - (iii) Mixed effect model with 'm' observations per cell.
18. IBD:
    - (i) Intrablock analysis
    - (ii) Inter block analysis
19. Complete s^m symmetrical factorial designs with s=3.

20. Completely confounded s^m symmetrical factorial designs with s=3, m=2.
21. Partially confounded s^m symmetrical factorial designs with s=3, m=2.
22. s^{k-p} fractional factorial designs with s=3, k(≤4).
23. Split-plot designs.

Semester-III

MSTC 301: Statistical Inference-II

Course Objectives: To make aware the students of parametric, non-parametric and sequential estimation (point, as well as, interval) and 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 estimation techniques and testing procedures to deal with real life problems.
2. Understand consistency, CAN estimator, MLE.
3. Understand UMPU tests, SPRT, OC and ASN.
4. Understand non-parametric methods, U-statistics, UMVU estimators.

Unit I: Consistency and asymptotic relative efficiency of estimators, Consistent asymptotic normal (CAN) estimator, Method of maximum likelihood, CAN estimator for one parameter Cramer family, Cramer-Huzurbazar theorem, Solutions of likelihood equations, method of scoring, Fisher lower bound to asymptotic variance, MLE in Pitman family and double exponential distribution, MLE in censored and truncated distributions.

Unit II: Similar tests, Neyman structure, UMPU tests for composite hypotheses, Invariance tests and UMP invariant tests, Likelihood ratio test, Asymptotic distribution of LRT statistic, Consistency of large sample test, Asymptotic power of large sample test.

Unit III: Sequential tests-SPRT and its properties, Wald's fundamental identity, OC and ASN functions. Sequential estimation.

Unit IV: Non- parametric methods-estimation and confidence interval, U-statistics and their asymptotic properties, UMVU estimator, nonparametric tests-single sample location, location-cum-symmetry, randomness and goodness of fit problems; Rank order statistics, Linear rank statistics, Asymptotic relative efficiency.

Suggested Readings:

1. Ferguson, T.S. (1967). Mathematical Statistics, Academic Press.
2. Gibbons, J.D. and Chakraborti, S. (1992). Nonparametric Statistical Inference, Marcel Dekker.
3. Kale, B.K. (1999). A First Course on Parametric Inference, Narosa Publishing House.
4. Lehmann, E.L. (1986). Theory of Point Estimation, John Wiley & Sons.
5. Lehmann, E.L. (1986). Testing Statistical Hypotheses, John Wiley & Sons.
6. Rohatgi, V.K. and Saleh, A.K.Md.E. (2005). An Introduction to Probability and Statistics, Second Edition, John Wiley.
7. Randles, R.H. and Wolfe, D.S. (1979). Introduction to the Theory of Non-parametric Statistics, John Wiley & Sons.
8. Rao, C.R. (1973). Linear Statistical Inference and Its Applications, 2nd Edn., Wiley Eastern Ltd.,
9. Sinha, S. K. (1986). Probability and Life Testing, Wiley Eastern Ltd.
10. Zacks, S. (1971). Theory of Statistical Inference, John Wiley & Sons.

Teaching Plan:

Week 1 : Consistency and asymptotic relative efficiency of estimators. Consistent asymptotic normal (CAN) estimator.

Week 2 : Method of maximum likelihood, CAN estimator for one parameter Cramer family.

Week 3: Cramer-Huzurbazar theorem.

Week 4: Solutions of likelihood equations, method of scoring.

Week 5: Fisher lower bound to asymptotic variance. MLE in Pitman family and double exponential distribution, MLE in censored and truncated distributions.

Week 6: Similar tests, Neyman structure, UMPU tests for composite hypotheses.

Week 7: Invariance tests and UMP invariant tests.

Week 8: Likelihood ratio test,

Week 9: Asymptotic distribution of LRT statistic, Consistency of large sample test, Asymptotic power of large sample test.

Week 10: Sequential tests-SPRT and its properties.

Week 11: Wald’s fundamental identity, OC and ASN functions. Sequential estimation.

Week 12: Non- parametric methods-estimation and confidence interval, U-statistics and their asymptotic properties.

Week 13: UMVU estimator, nonparametric tests-single sample location, location-cum-symmetry, randomness and goodness of fit problems; Rank order statistics.

Week 14: Linear rank statistics, Asymptotic relative efficiency.

MSTC 302: Multivariate Analysis

Course Objectives: The main objective of this course is to introduce students to the analysis of observations on several correlated random variables for a number of individuals. Such analysis becomes necessary in Anthropology, Psychology, Biology, Medicine, Education, Agriculture and Economics when one deals with several variables simultaneously.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Account for important theorems and concepts in multivariate analysis.
2. Summarize and interpret multivariate data.
3. Appreciate the range of multivariate techniques available.
4. Understand the link between multivariate techniques and corresponding univariate techniques.
5. Conduct statistical inference about multivariate means including hypothesis testing, confidence region calculation, etc.
6. Use multivariate techniques appropriately, and draw appropriate conclusions.
7. Analyse multivariate data using the SPSS statistical software package.

Unit I: Multivariate normal distribution, its properties and characterization. Random sampling from a multivariate normal distribution, Maximum likelihood estimators of parameters, Distribution of sample mean vector, Inference concerning the mean vector when the covariance matrix is known, Matrix normal distribution, Multivariate central limit theorem.

Unit II: Wishart matrix, its distribution and properties, Distribution of sample generalized variance, Hotelling's T^2 statistic, its distribution and properties, Applications in tests on mean vector for one and more multivariate normal populations and also on symmetry of organs, Mahalanobis' D^2.

Unit III: Likelihood ratio test criteria for testing independence of sets of variables, equality of covariance matrices, identity of several multivariate normal populations, equality of a covariance matrix to a given matrix, equality of a mean vector and a covariance matrix to a given vector and a given matrix, Distribution of the matrix of sample regression coefficients and the matrix of residual sum of squares and cross products, Rao's U-statistic, its distribution and applications.

Unit IV: Classification and discrimination procedures for discrimination between two multivariate normal populations, sample discriminant function, tests associated with discriminant functions, classification rule based on expected cost of misclassification (ECM), classification into more than two multivariate normal populations, Canonical correlation analysis, Principal components analysis, Elements of Factor analysis and cluster analysis, Multivariate analysis of variance (MANOVA) of one-way classified data, Wilk's lambda criterion.

Suggested Readings:

1. Anderson, T.W. (2003). An Introduction to Multivariate Statistical Analysis, 3rd ed., John Wiley & Sons.
2. Giri, N. C. (1977). Multivariate Statistical Inference, Academic Press.
3. Hardle, W. K. and Simar, L. (2015). Applied Multivariate Statistical Analysis, 4th Edn., Springer.
4. Johnson, R. A. and Wichern, D. W. (2015). Applied Multivariate Statistical Analysis, 6th Edn., Pearson Education India.
5. Kshirsagar, A. M. (1996). Multivariate Analysis, 2nd ed., Marcel Dekker.
6. Lawley, D. N. and Maxwell, A. E. (1971). Factor Analysis as a Statistical Method, 2nd Edn., London Butterworths.
7. Muirhead, R. J. (1982). Aspects of Multivariate Statistical Theory, John Wiley & Sons.
8. Rao, C. R. (1973). Linear Statistical Inference and its Applications, 2nd ed., John Wiley & Sons.
9. Srivastava, M. S. and Khatri, C. G. (1979). An Introduction to Multivariate Statistics, North Holland.

Teaching Plan:

Week 1-2: Multivariate normal distribution, its properties and characterization. Random sampling from a multivariate normal distribution. Maximum likelihood estimators of parameters.

Week 3 : Distribution of sample mean vector. Inference concerning the mean vector when the covariance matrix is known. Matrix normal distribution. Multivariate central limit theorem.

Week 4- 5: Wishart matrix, its distribution and properties. Distribution of sample generalized variance.

Week 6-7: Hotelling'sT^{2}statistic, its distribution and properties. Applications in tests on mean vector for one and more multivariate normal populations and also on symmetry of organs. Mahalanobis' D^2.

Week 8-9: Likelihood ratio test criteria for testing independence of sets of variables, equality of covariance matrices, identity of several multivariate normal populations, equality of a covariance matrix to a given matrix, equality of a mean vector and a covariance matrix to a given vector and a given matrix.

Week 10: Distribution of the matrix of sample regression coefficients and the matrix of residual sum of squares and cross products. Rao's U-statistic, its distribution and applications.

Week 11-12: Classification and discrimination procedures for discrimination between two multivariate normal populations, sample discriminant function, tests associated with discriminant functions, classification rule based on expected cost of misclassification (ECM), classification into more than two multivariate normal populations.

Week 13-14: Canonical correlation analysis. Principal components analysis. Elements of Factor analysis and cluster analysis. Multivariate analysis of variance (MANOVA) of one-way classified data, Wilk's lambda criterion.

MSTC 303: Generalized Linear Models

Course Objectives: The main objective of this course is to provide students the ability to learn and use linear and non-linear models for normal data, and generalized linear models for normal and non-normal responses.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Use linear and Non-linear models, apply data transformations, and appreciate the need and uses of generalized linear models.
2. Use logistic and Poisson regression models.
3. Understand deviance, analysis of deviance, Lack-of-Fit tests in Logistic and Poisson regression, and the concept of overdispersion.
4. Use Log linear models for contingency tables, and likelihood ratio tests for various hypotheses including independence, marginal and conditional independence, and partial association.
5. Understand graphical and non-graphical models.
6. Use the concepts of Generalized Linear Models in real life problems.
7. Understand and apply Quasi likelihood.

Unit I: Review of linear regression models, Residual Analysis, Transformation of response variable- Box-cox Method, Nonlinear regression models, Estimation of parameters and Statistical Inferences in nonlinear regression, Introduction to generalized linear models.

Unit II: Logistic and Poisson regression models: Logistic regression model for dichotomous data with single and multiple explanatory variables, ML estimation, large sample tests about parameters, Goodness-of-Fit tests (Concept of deviance), analysis of deviance, Lack-of-Fit tests in Logistic regression. Concept of overdispersion in logistic regression. Introduction to Poisson regression, MLE for Poisson regression, Applications in Poisson regressions.

Unit III: Log linear models for contingency tables: interpretation of parameters, ML estimation of parameters, likelihood ratio tests for various hypotheses including independence, marginal and conditional independence, and partial association. Graphical and decomposable models.

Unit IV: Family of Generalized Linear Models: Exponential family of distributions, Formal structure for the class of GLMs, Link functions, Likelihood equations for GLMs, Important distributions for GLMs, A class of link functions-the power function, Inference and residual analysis for GLMs, Overdispersion, Quasi likelihood.

Suggested Readings:

1. Agresti, A. (2002). Categorical Data Analysis, 2nd ed., John Wiley & Sons.
2. Bates. D.M. and Watts, D.G. (1988). Nonlinear Regression Analysis and Its Application, John Wiley & Sons.
3. Christensen, R. (1997). Log-linear Models and Logistic Regression, 2nd ed., Springer.
4. Collett, D. (2003). Modeling Binary Data, 2nd ed., Chapman and Hall, London.
5. Dobson, A.J. and Barnett, A.G. (2008). Introduction to Generalized Linear Models, 3rd ed., Chapman and Hall/CRC. London.
6. Green, P.J. and Silverman, B.W. (1994). Nonparametric Regression and Generalized Linear Models, Chapman and Hall, New York.
7. Hastie, T.J. and Tibshirani, R.J. (1990). Generalized Additive Models. 2nd ed., Chapman and Hall, New York.
8. Hosmer, D.W. and Lemeshow, S. (2000). Applied Logistic Regression, 2nd ed., John Wiley & Sons.
9. Lindsey, J. K. (1997). Applying generalized linear models, Springer-Verlag, New York.
10. Myers, R.H., Montgomery, D.C and Vining, G.G. (2002). Generalized Linear Models with Applications in Engineering and the Sciences, John Wiley & Sons.
11. McCulloch, C.E. and Searle, S.R. (2001). Generalized, Linear and Mixed Models, John Wiley & Sons.
12. McCullagh, P. and Nelder, J.A. (1989). Generalized Linear Models, 2nd ed., Chapman and Hall.

Teaching Plan:

Week 1 : Review of linear regression models, Residual Analysis, Transformation of response variable- Box-cox Method.

Week 2-3 : Nonlinear regression models, Estimation of parameters and Statistical Inferences in nonlinear regression, Introduction to generalized linear models, Logistic and Poisson regression models.

Week 4-5: Logistic regression model for dichotomous data with single and multiple explanatory variables, ML estimation, large sample tests about parameters, Goodness-of-Fit tests (Concept of deviance), and analysis of deviance.

Week 6-7: Lack-of-Fit tests in Logistic regression. Concept of overdispersion in logistic regression, Introduction to Poisson regression, MLE for Poisson regression, Applications in Poisson regressions.

Week 8- 9: Log linear models for contingency tables: interpretation of parameters, ML estimation of parameters.

Week 10-11: Likelihood ratio tests for various hypotheses including independence, marginal and conditional independence, and partial association, graphical and decomposable models.

Week 12-13: Family of Generalized Linear Models: Exponential family of distributions, Formal structure for the class of GLMs, Link functions, Likelihood equations, ML estimation, Important distributions for GLMs.

Week 14: A class of link functions-the power function, Inference and residual analysis for GLMs, overdispersion, Quasi likelihood.

MSTE 304 (i): Bio-Statistics

Course Objectives: Biostatistics is one area of Applied Statistics that concerns itself with the application of statistical methods to medical, biological, epidemiological and health related problems.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Tackle the challenges associated with the study design and data analysis conducted in the health sciences.
2. Use and understand the principal numeric and graphical techniques to display and summarize medical and health related data.
3. Understand the basic principles of probability and how they relate to biostatistics.
4. Studying the relationship between a vector of covariates x and the rate of occurrence of specific types of failure
5. Analyze whether people at high risk of one type of failure are also at high risk for others, even after controlling for covariates
6. Estimating the risk of one type of failure after removing others
7. Evaluate, from simple datasets, evidence for linkage disequilibrium and disease associations using basic association tests
8. Discuss the wider issues involved in applying association tests to whole genomes.
9. Formulate and analyze stochastic epidemic models for specific purposes
10. Understand modelling epidemics with a structured underlying population.
11. Understand How to handle censored data, estimation of Kaplan-Meier survivor curves, the Log-Rank test for testing differences between survival curves, and Cox' regression model for estimating and testing effects of covariates (and interpretation of the statistical results).
12. Understand the introduction to basic statistics for clinical trials.

Unit I: Functions of survival time, survival distributions and their applications viz. exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shape hazard function. Different type of censoring viz. right (type I), left, double, interval and number censoring (type II) with real life examples. Estimation of mean survival time and variance of the estimator for type I and type II censored data with numerical examples. Non-parametric methods for estimating survival function and variance of the estimator viz. Acturial and Kaplan –Meier methods. Parametric methods viz. Likelihood Ratio test, Cox's F-test and non-parametric methods viz. Log Rank test, Cox F test for comparing two survival distributions, Cox proportional hazard model.

Unit II: Analysis of Epidemiologic and Clinical Data: Studying association between a disease and a characteristic: (a) Types of studies in Epidemiology and Clinical Research (i) Prospective study (ii)Retrospective study (iii) Cross-sectional data, (b) Dichotomous Response and Dichotomous Risk Factor: 2x2 Tables (c) Expressing relationship between a risk factor and a disease (d) Inference for relative risk and odds ratio for 2x2 table, Sensitivity, specificity and predictivities, Competing risk theory, Indices for measurement of probability of death under competing risks and their inter-relations. Estimation of probabilities of death under competing risks by maximum likelihood and modified minimum Chi-square methods. Theory of independent and dependent risks, Bivariate normal dependent risk model. Conditional death density functions.

Unit III: Stochastic epidemic models: Simple and general epidemic models (by use of random variable technique). Basic biological concepts in genetics, Mendels law, Hardy-Weinberg equilibrium, random mating, distribution of allele frequency (dominant/co-dominant cases), Approach to equilibirium for X-linked genes, natural selection, mutation, genetic drift, equilibirium when both natural selection and mutation are operative, detection and estimation of linkage in heredity.

Unit IV: Planning and design of clinical trials, Phase I, II, and III trials. Consideration in planning a clinical trial, designs for comparative trials. Sample size determination in fixed sample designs.

Suggested Readings:

1. Biswas, S. (1995). Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, Wiley Eastern Ltd.
2. Collett, D. (2003). Modelling Survival Data in Medical Research, Chapman & Hall/CRC.
3. Cox, D.R. and Oakes, D. (1984). Analysis of Survival Data, Chapman and Hall.
4. Ewens, W. J. and Grant, G.R. (2001). Statistical methods in Bio informatics: An Introduction, Springer.

5. Ewens, W. J. (1979). Mathematics of Population Genetics, Springer Verlag.
6. Elandt Johnson R.C. (1971). Probability Models and Statistical Methods in Genetics, John Wiley & Sons.
7. Friedman, L.M., Furburg, C. and DeMets, D.L. (1998). Fundamentals of Clinical Trials, Springer Verlag.
8. Gross, A. J. And Clark V.A. (1975). Survival Distribution; Reliability Applications in Biomedical Sciences, John Wiley & Sons.
9. Indrayan, A. (2008). Medical Biostatistics, 2nd ed., Chapman & Hall/CRC.
10. Lee, Elisa, T. (1992). Statistical Methods for Survival Data Analysis, John Wiley & Sons.
11. Li, C.C. (1976). First Course of Population Genetics, Boxwood Press.
12. Miller, R.G. (1981). Survival Analysis, John Wiley & Sons.
13. Robert F. Woolson (1987). Statistical Methods for the analysis of biomedical data, John Wiley & Sons.

Teaching Plan:

Week 1 : Functions of survival time, survival distributions and their applications viz. exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shape hazard function.

Week 2 : Different types of censoring viz. right (type I), left, double, interval and number censoring (type II) with real life examples. Estimation of mean survival time and variance of the estimator for type I and type II censored data with numerical examples.

Week 3: Non-parametric methods for estimating survival function and variance of the estimator viz. Acturial and Kaplan –Meier methods.

Week 4: Parametric methods viz. Likelihood Ratio test, Cox's F-test for comparing two survival distributions.

Week 5: Non-parametric methods viz. Log Rank test, Cox F test for comparing two survival distributions, Cox proportional hazard model.

Week 6: Analysis of Epidemiologic and Clinical Data: Studying association between a disease and a characteristic. Types of studies in Epidemiology and Clinical Research (i) Prospective study (ii) Retrospective study (iii) Cross-sectional study.

Week 7: Dichotomous Response and Dichotomous Risk Factor: 2x2 Tables (c) Expressing relationship between a risk factor and a disease (d) Inference for relative risk and odds ratio for 2x2 table.

Week 8: Sensitivity, specificity and predictivities, Competing risk theory, Indices for measurement of probability of death under competing risks and their inter-relations.

Week 9: Estimation of probabilities of death under competing risks by maximum likelihood and modified minimum Chi-square methods. Theory of independent and dependent risks, Bivariate normal dependent risk model. Conditional death density functions.

Week 10: Stochastic epidemic models: Simple and general epidemic models (by use of random variable technique).

Week 11: Basic biological concepts in genetics, Mendels law, Hardy- Weinberg equilibirium, random mating, distribution of allele frequency (dominant/co-dominant cases).

Week 12: Approach to equilibirium for X-linked genes, natural selection, mutation, genetic drift, equilibirium when both natural selection and mutation are operative, detection and estimation of linkage in heredity.

Week 13: Planning and design of clinical trials, Phase I, II, and III trials. Consideration in planning a clinical trial.

Week 14: Sample size determination in fixed sample designs.

List of Practicals:

1. Comparison of two survival distributions (Parametric as well as non- parametric).
2. Cox PH model
3. Competing risk theory
4. Sensitivity analysis
5. Determination of sample size in clinical trials.

MSTE 304(ii): Operational 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 characteristics of different types of decision-making environments and decision making approaches.
3. Understand the mathematical tools that are needed to solve optimization problems.
4. Analyze the queueing and inventory situations.
5. Understand discrete event simulation and decision analysis with inclusion of modelling based on random events involving uncertainties.
6. Conceptualise optimum event management through Network scheduling'

Unit I: Definition and Scope of Operational Research, Phases in Operational Research, Different types of models and their construction.

Simulation: Types and classifications. Pseudorandom Number Generation, Using random numbers to evaluate integrals, Generating discrete and continuous random variables: Inverse Transform Method, Acceptance-Rejection Technique, Composition Approach**.** Simulating discrete events

Unit II: Introduction to Decision Analysis: Pay-off table for one-off decisions and discussion of Decision criteria, Decision trees.

Quadratic programming: Beale's and Wolfe's methods. Network Scheduling: CPM, PERT.

Unit III: Queueing Theory: Steady state analysis of M/M/1, M/M/C queues, Method of stages for steady state solution of M/Er/1 and Er/M/1 queues.

Unit IV: Inventory Management: Characteristics of inventory systems. Classification of items. Deterministic inventory systems with and without lead-time. All units and incremental discounts. Single period stochastic models.

Suggested Readings:

1. Banks J. (1998). Handbook of Simulation: Principles, Methodology, Advances, Applications and Practice, John Wiley and Sons.
2. Gross, D., Shortle J.F., Thompson J.M. and Harris, C.M. (2008). Fundamentals of Queueing Theory, John Wiley & Sons.
3. Hillier, F.S. and Lieberman, G.J. (2001). Introduction to Operations Research, 7^{th} ed., Irwin.
4. Hadley, G. and Whitin, T.M. (1963). Analysis of Inventory Systems, Prentice Hall.
5. Ross, S. M. (2013). Simulation, Fifth Ed., Academic Press.
6. Taha, H. A. (2016) .Operations Research: An Introduction, Tenth Ed. Prentice Hall.
7. Winston, W.L. and Goldberg, J.B. (2004). Operations Research: Applications and Algorithms, Thomson Brooks/Cole.

Teaching Plan:

Week 1 : Definition and Scope of Operational Research, Phases in Operational Research, Different types of models, their construction approach. Simulation: Types and classifications.

Week 2 : Pseudorandom Number Generation. Using Random Numbers to Evaluate Integrals. Some more Applications.

Week 3: Generating Discrete Random Variables: Inverse Transform Method, Acceptance-Rejection Technique, Composition Approach.

Week 4: Generating Continuous Random Variables: Inverse Transform Method, Acceptance-Rejection Technique, Composition Approach.

Week 5: Simulating discrete events.

Week 6: Introduction to Decision Analysis: Pay-off tables and Discussion of Decision Criteria.

Week 7: Decision Trees.

Week 8: Quadratic Programming: Beale’s and Wolfe’s methods.

Week 9: Network Scheduling: CPM.

Week 10: Network Scheduling: PERT.

Week 11: Queueing Theory: Steady State Analysis of M/M/1 queues.

Week 12: Queueing Theory: Steady State Analysis of M/M/C queues.

Week 13: Queueing Theory: Method of Stages for Steady State Solution of M/Er/1 and Er/M/1 queues.

Week 14: Inventory Management: Characteristics of Inventory Systems. Classification of items. Deterministic Inventory Systems with and without Lead-Time. All units and incremental discounts. Single period stochastic models.

List of Practicals

1. Evaluating Integrals
2. Discrete Event Simulation
3. Quadratic Programming
4. Network Scheduling
5. Decision Trees
6. Markvian Queues

MSTE 304 (iii): Nonparametric Inference

Course Objectives: This course will provide the ability to learn the fundamentals of the most relevant nonparametric techniques for statistical inference.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Solve hypothesis testing problems where the conditions for the traditional parametric inferential tools to be applied are not fulfilled.
2. Build nonparamteric density estimates.

Unit I: Review of order statistics, Distribution-free statistics over a class, Counting statistics, ranking statistics, Statistics utilizing counting and ranking, Asymptotic distribution of U-statistics, Confidence interval for population quantile and scale parameter, point estimation. Estimators associated with distribution free test statistics, Exact small-sample and asymptotic properties of the Hodges-Lehmann location estimators.

Unit II: Nonparametric density estimation, nonparametric regression estimation. Tests based on length of the longest run, runs up and down, Kolmogorov-Smirnov two sample statistic.

Rank order statistics: Correlation between ranks and variate values, One sample, paired sample and two sample problems, distribution properties of linear rank statistics.

Unit III: Tests for equality of k independent samples: Kruskal-Wallis one way ANOVA test, Measures of Association for bivariate samples: Kendall's Tau coefficient, Spearman's coefficient of Rank correlation, relations between R and T; E (R), τ and ρ.

Unit IV: Measures of association in multiple classifications: Friedman's two-way ANOVA by ranks in a k x n table, the Coefficient of Concordance of k sets of rankings of n objects, the Coefficient of Concordance of k sets of incomplete rankings. Concept of power and robustness, elements of bootstrapping.

Suggested Readings:

1. David, H.A. and Nagaraja, H. N. (2003). Order Statistics, Third Edition, John Wiley & Sons.
2. Gibbons, J.D. and Chakraborti, S. (1992). Nonparametric Statistical Inference, 3rd ed., Marcel Dekker.
3. Hettmansperger, T.P. (1984). Statistical inference Based on Ranks, John Wiley & Sons.
4. Randles, R.H. and Wolfe, D.A. (1979). Introduction to the Theory of Nonparametric Statistics, John Wiley & Sons.
5. Rohatgi, V.K. and Saleh, A.K. Md. E. (2005). An Introduction to Probability and Statistics, 2^{nd} ed., John Wiley & Sons.

Teaching Plan:

Week 1 : Review of order statistics, Distribution-free statistics over a class, Counting statistics, ranking statistics, Statistics utilizing counting and ranking.

Week 2 : Asymptotic distribution of U-statistics, Confidence interval for population quantile and scale parameter.

Week 3: Point estimation. Estimators associated with distribution free test statistics.

Week 4: Exact small-sample and asymptotic properties of the Hodges-Lehmann location estimators.

Week 5: Nonparametric density estimation, Nonparametric regression estimation. Tests based on length of the longest run, runs up and down.

Week 6: Kolmogorov-Smirnov two sample statistic. Rank order statistics: Correlation between ranks and variate values.

Week 7: One sample, paired sample and two sample problems, distribution properties of linear rank statistics.

Week 8: Tests for equality of k independent samples: Kruskal-Wallis one way ANOVA test.

Week 9: Measures of Association for bivariate samples: Kendall's Tau coefficient.

Week 10: Spearman's coefficient of Rank correlation, relations between R and T; E (R), τ and ρ.

Week 11: Measures of association in multiple classifications: Friedman's two-way ANOVA by ranks in a k x n table.

Week 12-13: Coefficient of Concordance of k sets of rankings of n objects, Coefficient of Concordance of k sets of incomplete rankings.

Week 14: Concept of power and robustness, elements of bootstrapping.

List of Practicals:

1. Confidence interval for population quantile and scale parameter.
2. Point estimation. Estimators associated with distribution free test statistics.
3. Kolmogorov-Smirnov two sample statistic.
4. Correlation between ranks and variate values
5. One sample, paired sample and two sample problems.
6. Kruskal-Wallis one way ANOVA test.
7. Kendall's Tau coefficient.
8. Spearman's coefficient of Rank correlation, relations between R and T; E (R), τ and τ.
9. Friedman's two-way ANOVA by ranks in a k x n table.
10. Coefficient of Concordance of k sets of rankings of n objects.
11. Coefficient of Concordance of k sets of incomplete rankings.

MSTE 304 (iv): Financial Statistics

Course Objectives: Financial Statistics aims to introduce students to the market tools required for analyzing the financial markets, to model various financial instruments and to find solutions of the problems faced by various players of these markets.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Understand the intricacies of the derivatives markets and analyse them quantitatively.
2. Model and analyze the jumps observed in security markets.
3. Take up research to be able to attempt to fill the gap between the markets and academics.

Unit I: Review and Extensions- Assets, Portfolios and Arbitrage, Derivatives, Pricing, Hedging, Greeks, Discrete Time Models, Continuous Time Models, Random walk, Geometric Random Walk, Brownian Motion, Wiener Process.

Unit II: Review and Extensions- Stochastic Calculus, Stochastic Differential Equations, Partial Differential Equations, Black- Scholes' PDE, Martingales and their Applications in Pricing of Assets, Plain Vanilla Options, Greeks of Plain Vanilla Options, Estimation of Volatility, CRR Model.

Unit III: Financial Markets Instruments- Exotic Options, Reflection Principle, Asian Options, Change of Numeraire, Pricing of Exchange Options, Forward Rates Modelling, Forward Vesicek Rates, Interest Rates Derivatives and their Pricing, Default Risk in Bond Markets, Credit Default Swaps.

Unit IV: Jump Processes- Poisson Process, Compound Poisson Processes, Stochastic Integrals with Jumps, Itô- Integral with Jumps, Stochastic Differential Equations with Jumps, Girsanov Theorem for Jumps Processes, Lèvy Processes, Pricing and Hedging in Jump Processes, Risk Neutral Measures, Black Scholes' PDE with jumps.

Suggested Readings:

1. Lamberton, D. and Lepeyre, B. (2008). Introduction to Stochastic Calculus Applied to Finance, 2nd ed., Chapman and Hall/CRC Press.

2. Privault, N. (2014). Stochastic Finance –An Introduction with Market Examples, Chapman and Hall/CRC. Financial Mathematics Series, CRC Press, Boca Raton, 2014.
3. Tankov, P. (2010). Financial Modeling with Lèvy Processes, e-Book.

Teaching Plan:

Week 1 : Assets, Portfolios and Arbitrage, Derivatives, Pricing, Hedging, Greeks.

Week 2 : Discrete Time Models, Continuous Time Models, Random walk.

Week 3: Geometric Random Walk, Brownian Motion, Wiener Process.

Week 4: Stochastic Calculus, Stochastic Differential Equations, Partial Differential Equations, Black- Scholes' PDE.

Week 5: Martingales and their Applications in Pricing of Assets.

Week 6: Plain Vanilla Options, Greeks of Plain Vanilla Options, Estimation of Volatility, CRR Model.

Week 7: Exotic Options, Reflection Principal, Asian Options.

Week 8: Change of Numeraire, Pricing of Exchange Options.

Week 9: Forward Rates Modelling, Forward Vesicek Rates, Interest Rates Derivatives and their Pricing.

Week 10: Default Risk in Bond Markets, Credit Default Swaps.

Week 11: Poisson Process, Compound Poisson Processes, Stochastic Integrals with Jumps, Itô- Integral with Jumps.

Week 12: Stochastic Differential Equations with Jumps, Girsanov Theorem for Jumps Processes.

Week 13: Lèvy Processes.

Week 14: Pricing and Hedging in Jump Processes, Risk Neutral Measures, Black Scholes' PDE with jumps.

List of Practicals:

1. Simulation of A Wiener process.
2. Pricing of Assets using Black scholes' model.
3. Pricing of Assets using CRR model.
4. Static and dynamic hedging.
5. Estimation of volatility.
6. Pricing of exotic options.
7. Simulation of Vesicek model.

8. Calculating the risk of bond markets.
9. Simulating a Poisson process.
10. Pricing and Hedging in Jump Processes.

MSTP 305: Practical –III

Part-A: Problem Solving using R Software-I

(Statistical Computing-II)

Mathematical and Statistical problem solving using software package: Introduction, Plots in 2-D and 3-D. Vector and matrix operations.

Numerical Methods required for statistical problem solving: Errors in numerical computations; solution of - algebraic and transcendental equations, system of linear equations Eigen value and eigenvectors of a matrix; Integration; ordinary differential equations.

Simulating statistical models– Poisson Process, Markov Chain, Markov jump process. Monte Carlo methods–Introduction, Monte-Carlo integration, Application to Inferential Statistics.

Suggested Readings:

1. Gentle, J.E., Härdle W. and Mori Y. (2004). Handbook of computational statistics: Concepts and methods, Springer-Verlag.
2. Monahan, J.M. (2001). Numerical Methods in Statistics, Cambridge.
3. Robert, C.P. and Casella, G. (2004). Monte Carlo Statistical Methods, 2^{nd} ed., Springer.
4. Voss, J. (2014). An introduction to statistical computing: a simulation-based approach, First edition. Wiley series in computational statistics.

Part B: Problem Solving using SPSS-I

List of Practicals:

1. Problems based on estimation of reliability based on complete and censored samples.
2. Problems based on method of maximum likelihood on complete and censored samples.
3. Problems based on UMVU estimators.
4. Problems based on Likelihood ratio test.
5. Problems based on SPRT.
6. Problems based on construction of OC and ASN curves.
7. Some problems based on non-parametric tests.

8. Multivariate normal distribution.
9. Marginal and conditional distributions. Regression functions.
10. Testing hypothesis about mean vector when covariance matrix is known.
11. Testing problems based on Hotelling's T^2 – one sample, two sample, q-samples.
12. Likelihood ratio test for testing the independence of sub-vectors.
13. Likelihood ratio test for testing the equality of several dispersion matrices.
14. Problems based on discrimination between two multivariate normal populations.
15. Principal components.
16. Canonical correlations.
17. Use of transformation of response variable- Box-cox Method.
18. Fitting of non-linear regression model.
19. Fitting of logistic regression model.
20. Fitting of Poisson regression model.
21. Log linear models for contingency tables.
22. Tests for independence, marginal and conditional independence, partial association.
23. Fitting of GLM.

Semester-IV

MSTC 401: Econometrics and Time Series Analysis

Course Objectives: The objective of this course is to study more advanced topics in econometrics and time series viz. MA, AR, ARMA, ARIMA Models, G.L.M. 2-SLS, 3-SLS estimators and Granger Causality Test.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Acquire knowledge of various advanced econometric models, estimation methods and related econometric theories.
2. Conduct econometric analysis of data.
3. Apply statistical techniques to model relationships between variables and make predictions.
4. Understand Auto-covariance, auto-correlation function and Vector Autoregression.
5. Understand Correlogram and Periodogram analysis and different Smoothing methods.

Unit I: Econometrics: Review of GLM and generalized least squares, GLM with stochastic regressors, Instrumental Variables (I.V): estimation, consistency property, asymptotic variance of I.V estimators. Bayesian analysis of Linear Model with Non Informative Priors and Conjugate Priors. Bayes estimation and testing of hypothesis of regression coefficients.

Unit II: Distributed lag models, Polynomial lag models, Almon's lag model, Determination of degree of polynomial and lag length. Adaptive expectation model, Partial adjustment model, Compound Geometric lag model. Methods of estimation. Vector Auto Regression (VAR), the Granger Causality Test.

Unit III: Simultaneous-equation models: Identification problems. Restrictions on structural parameters – Rank and Order Condition for identification. Restrictions on variances and covariances. Simultaneous-equation methods: Estimation - Recursive systems, Two Stage Least Squares (2SLS) estimators, Limited Information (Least Variance Ratio) estimators, k-class estimators, Three Stage Least Squares (3SLS) and Full Information Maximum-Likelihood (FIML).

Unit IV: Time series as discrete parameter stochastic process. Auto-covariance and Auto-correlation functions and their properties. Stationary Processes: Moving average (MA) process, Auto-regressive (AR) process, ARMA, ARIMA and SARIMA models. Box-Jenkins models, Discussion (without proof) of estimation of mean, auto-covariance auto-correlation functions under large sample theory. Linear Filter: Auto regressive processes, Moving average processes. Correlogram and Periodogram analysis. Spectral representation of time series. Problems associated with estimation of spectral densities, Properties of spectral densities. Spectrum theory, smoothing the spectrum. Forecasting. Exponential smoothing methods, Direct smoothing and adaptive smoothing.

Suggested Readings:

1. Basu, A.K. (2003). Introduction to Stochastic Process, Narosa Publishing House Pvt. Ltd., India
2. Brockwell, P.J. and Daris, R. A. (2002). Introduction to time Series and Forecasting, 2nd ed., Springer-Verlag.
3. Greene, W.H. (2003). Econometric Analysis, 5th ed., Dorling Kindersley (India) Pvt. Ltd., licensees of Pearson Education in South Asia.
4. Johnston, J. (1984). Econometric Methods, McGraw Hill Kogakusha Ltd.
5. Judge, G.G., Hill, R, C., Griffiths, W.E., Lutkepohl, H. and Lee, T.C. (1988). Introduction to the Theory and Practice of Econometrics, 2nd ed., John Wiley & Sons.
6. Kmenta, J. (1986). Elements of Econometrics, 2nd ed., Mac Millan.
7. Kendall, M.G. and Stuart, A. (1968). The Advanced Theory of Statistics, Vol. III, 2nd ed., Charles Griffin.
8. Medhi, J. (1994). Stochastic Processes, 2nd Edn., Wiley Eastern, New Delhi
9. Montgomery, D.C. and Johnson, L.A. (1976). Forecasting and Time Series Analysis, McGraw Hill.

Teaching Plan:

Week 1 : Econometrics: Review of GLM and generalized least squares, GLM with stochastic regressors, Instrumental Variables (I.V.): estimation, consistency property, asymptotic variance of I.V. estimators.

Week 2 : Bayesian analysis of Linear Model with Non Informative Priors and Conjugate Priors. Bayes estimation and testing of hypothesis of regression coefficients.

Week 3: Distributed lag models, Polynomial lag models, Almon's lag model, Determination of degree of polynomial and lag length.

Week 4: Adaptive expectation model, Partial adjustment model, Compound Geometric lag model. Methods of estimation.

Week 5: Vector Auto Regression (VAR), The Granger Causality Test. Simultaneous-equation models.

Week 6: Identification problems. Restrictions on structural parameters – Rank and Order Condition for identification.

Week 7: Restrictions on variances and covariances. Simultaneous equation methods: Estimation - Recursive systems.

Week 8: Two Stage Least Squares (2SLS) estimators, Limited Information (Least Variance Ratio) estimators.

Week 9: k-class estimators. Three Stage Least Squares (3SLS) and Full Information Maximum- Likelihood (FIML).

Week 10: Time series as discrete parameter stochastic process. Auto-covariance and Auto-correlation functions and their properties. Stationary Processes: Moving average (MA) process, Auto-regressive (AR) process,

Week 11: ARMA, ARIMA and SARIMA models. Box-Jenkins models, Discussion (without proof) of estimation of mean, auto-covariance auto-correlation functions under large sample theory.

Week 12: Linear Filter: Auto regressive processes, Moving average processes. Correlogram and Periodogram analysis. Spectral representation of time series

Week 13: Problems associated with estimation of spectral densities, Properties of spectral densities. Spectrum theory, smoothing the spectrum.

Week 14: Forecasting. Exponential smoothing methods, Direct smoothing and adaptive smoothing.

MSTC 402: Demography, Statistical Quality Control and Reliability

Course Objectives: The main objective of this course is to describe current population trends, in terms of fertility, mortality and population growth and the concepts of Statistical Quality Control, Quality Assurance and Performance Analysis.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Identify principle sources of demographic data and assess their strengths and weaknesses.
2. Discuss the demographic significance of age structures and the implications of variations in age structure.
3. Construct and interpret single-decrement life tables.
4. Specify and calculate the principal demographic measures, and standardize these measures for comparison and interpretation.
5. Identify the components of population change, including the effects of changing birth, death and migration rates, and demonstrate their influences on age structure.
6. Do population projection by different methods.
7. Describe the DMAIC process (define, measure, analyze, improve, and control).
8. Demonstrate to use the methods of statistical process control and to determine when an out-of-control situation has occurred.
9. Design and use Cumulative sum chart, tabular Cumulative sum chart and V-mask schemes for detecting small shifts of the mean from goal conditions.
10. Choose an appropriate sampling inspection technique.
11. Understand the importance of validity and reliability assessment and the link between the two.
12. Estimate the reliability function and mean time to failure for different types of systems.
13. Estimate the survival time under PMP.

Unit I: Demography: Measures of mortality, description of life table, construction of complete and abridged life tables, maximum likelihood, MVU and CAN estimators of life table parameters. Measures of fertility, models for population growth, intrinsic growth rate, stable population analysis, population projection by component method and using Leslie matrix.

Unit II: Basic concepts of process monitoring and control, General theory and review of control charts, OC and ARL of control charts, CUSUM charts using V-mask and decision intervals, economic design of $\bar{x}$ chart.

Unit III: Review of sampling inspection techniques, single, double, multiple and sequential sampling plans and their properties, methods for estimating (n, c) using large sample and Bayesian techniques, curtailed and semi-curtailed sampling plans, Dodge's continuous sampling inspection plans for inspection by variables for one-sided and two-sided specifications.

Unit IV: Reliability: Reliability concepts and measures, components and systems, reliability function, hazard rate, common life distributions viz. exponential, gamma, Weibull, lognormal, Rayleigh, piece-wise exponential etc., Reliability and expected survivability of series, parallel, mixed, maintained and non-maintained systems with and without redundancy, preventive maintenance policy.

Suggested Readings:

1. Biswas, S. (1996). Statistics of Quality Control, Sampling Inspection and Reliability, New Age International Publishers.
2. Bain, L. J and Engelhardt, M. (1991). Statistical Analysis of Reliability and Life Testing Models, Marcel Dekker.
3. Biswas, S. (1988). Stochastic Processes in Demography and Applications, Wiley Eastern Ltd.
4. Barlow, R. E. And Proschan, F (1985). Statistical Theory of Reliability and Life Testing, Holt, Rinehart and Winston.
5. Chiang, C.L. (1968). Introduction to Stochastic Processes in Bio statistics, John Wiley.
6. Keyfitz, N. (1971). Applied Mathematical Demography, Springer Verlag.
7. Lawless, J. F. (1982). Statistical Models and Methods of Life Time Data, John Wiley & Sons.
8. Montgomery, D. C. (2005). Introduction to Statistical Quality Control, 5th ed., John Wiley & Sons.
9. Spiegelman, M. (1969). Introduction to Demographic Analysis, Harvard University Press.
10. Wetherill, G. B. (1977). Sampling Inspection and Quality Control, Halsted Press.

Teaching Plan:

Week 1 : Demography: Measures of mortality, description of life table, construction of complete and abridged life tables.

Week 2 : Maximum likelihood, MVU and CAN estimators of life table parameters.

Week 3: Measures of fertility, models for population growth.

Week 4: Intrinsic growth rate, stable population analysis, population projection by component method and using Leslie matrix.

Week 5: Basic concepts of process monitoring and control, General theory and review of control charts.

Week 6: OC and ARL of control charts, CUSUM charts using V-mask and decision intervals

Week 7: Economic design of x- bar chart, review of sampling inspection techniques.

Week 8: Single sampling plan with properties, methods for estimating (n, c) using large sample and Bayesian techniques.

Week 9: Curtailed and semi-curtailed single sampling plans, double, multiple and sequential sampling plan.

Week 10: Dodge’s continuous sampling inspection plan.

Week 11: Reliability: Reliability concepts and measures, components and systems.

Week 12: Reliability function, hazard rate, common life distributions viz. exponential, gamma, Weibull, lognormal, Rayleigh, piece-wise exponential etc.

Week 13: Reliability and expected survivability of series, parallel, mixed systems.

Week 14: Reliability and expected survivability of maintained and non-maintained systems with and without redundancy, Preventive maintenance policy.

MSTE 403 - 404 (i): Applied Stochastic Processes

Course Objectives: The course objectives of this paper is to provide understanding of mathematical challenges from a purely applied perspective for a majority of random processes in terms of sequence of event-time pairs.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Make assumptions about the way in which scenarios based on random processes develop.
2. Create realistic model for real time situation and to seek solutions to systems oriented problems.
3. Construct approximate theoretical solutions and simulation analysis.
4. Theoretical derivations and results based on theorems are exhaustively dealt with.

Unit I: Discrete Time Markov Chain**:** Deterministic and Stochastic approach to SIS Epidemic Model, Chain Binomial Greenwood and Reed-Frost Models. Determination of size and Duration.

Review of Mathematical expectation, Generating Functions, Central Limit Theorem. Poisson Process: Generator Matrix, Kolmogorov Differential Equations, Stationary Probability Distribution.

Unit II: General Birth and Death Process, Simple Birth and Simple Death with Immigration, Population Extinction, First Passage Times, Logistic Growth Processes.

Unit III: Continuous Time Markov Chain**:** Deterministic and Stochastic approach to SIR Epidemic Model. Determination of size and Duration. Deterministic and Stochastic approach to Competition Process. Deterministic and Stochastic approach to Predator-Prey Process.

Unit IV: Diffusion Process and Stochastic Differential Equations. Some Applications.

Suggested Readings:

1. Bailey, N.T.J. (1964). The Elements of Stochastic Processes, John Wiley & Sons.

2. Bhat, B.R. (2000). Stochastic Models: Analysis and Applications, New Age International Publishers.
3. Feller, William (1968). An Introduction to Probability Theory and its Applications, Vol. I 3rd Edn., John Wiley & Sons.
4. Karlin, S. and Taylor, H.M. (1975). A first course in Stochastic Processes, 2nd ed., Academic Press.
5. Lange, K. (2010). Applied Probability, 2nd ed., Springer.
6. Prabhu, N.U. (2007). Stochastic Processes: Basic Theory and its Applications, World Scientific.
7. Ross, S. M. (1996). Stochastic Processes, John Wiley & Sons.
8. Taylor, H.M. and Karlin, S. (1998). An Introduction To Stochastic Modelling, 3rd ed., Academic Press.

Teaching Plan:

Week 1- 2 : Deterministic and Stochastic approach to SIS Epidemic Model, Chain Binomial Greenwood and Reed-Frost Models. Determination of size and Duration.

Week 3-4 : Review of Mathematical expectation, Generating Functions, Central Limit Theorem. Poisson Process: Generator Matrix, Kolmogorov Differential Equations**,** Stationary Probability Distribution.

Week 5- 6: General Birth and Death Process, Simple Birth and Simple Death with Immigration.

Week 7-8: Population Extinction, First Passage Times**,** Logistic Growth Processes.

Week 9-10: Deterministic and Stochastic approach to SIR Epidemic Model, Determination of size and Duration.

Week 11: Deterministic and Stochastic approach to Competition Process.

Week 12: Deterministic and Stochastic approach to Predator-Prey Process.

Week13-14: Diffusion Process and Stochastic Differential Equations.

List of Practicals:

1. Generate Simple Birth Process.
2. Generate Simple Birth and Death Process.
3. Simulate Probability of Population Extinction.
4. Some Biological Applications.

MSTE 403 - 404(ii): Order Statistics

Course Objectives: The objective of this course is to make the students aware of the properties and applications of order statistics.

Course Learning Outcomes:

On successful completion of the course the student will be able to:

1. Find joint, marginal and conditional probability distributions of order statistics in the continuous and discrete cases.
2. Find the distribution of sample range and other systematic statistics in case of sampling from an arbitrary continuous population and, in particular, from some specific continuous distributions such as uniform and exponential.
3. Understand the Markov Chain property of order statistics in the continuous case.
4. Learn how to obtain distribution-free confidence intervals for population quantile and distribution-free tolerance intervals for population distributions based on order statistics.
5. Understand the distribution-free bounds for moments of order statistics and of the range.
6. Find the approximations to moments of order statistics in terms of quantile function and its derivatives.
7. Derive the recurrence relations and identities for moments of order statistics drawn from an arbitrary population (discrete or continuous), as well as from some specific distributions.
8. Appreciate the large sample approximations to the mean and variance of order statistics as well as the asymptotic distributions of order statistics.
9. Find the distributions of order statistics for independently and not identically distributed variates and also for dependent variates.
10. Learn about the concomitants of order statistics and their properties.
11. Understand random division of an interval and its applications in geometrical probabilities.
12. Learn about the joint and marginal distributions of order statistics from a sample containing a single outlier.
13. Learn about the two candidates Ballot Box problem, its extension, generalization and application to fluctuations of sums of random variables.
14. Learn about the basic concepts of record values and generalized order statistics.

Unit I: Introduction to order statistics. Basic distribution theory. Joint and marginal distributions of order statistics in the continuous case. Distribution of the range and other systematic statistics. Conditional distributions. Order statistics as a Markov Chain. Order statistics for a discrete parent. Examples based on discrete and continuous distributions.

Unit II: Distribution-free confidence intervals for population quantiles and distribution-free tolerance intervals. Distribution-free bounds for moments of order statistics and of the range. Approximations to moments in terms of the quantile function and its derivatives.

Unit III: Moments of order statistics. Recurrence relations and identities for moments of order statistics from an arbitrary distribution. Recurrence relations for moments of order statistics from some specific distributions. Large sample approximations to mean and variance of order statistics. Asymptotic distributions of order statistics.

Unit IV: Order statistics for independently and not identically distributed (i.ni.d.) variates. Order statistics for dependent variates. Concomitants of order statistics. Random division of an interval and its applications. Order statistics from a sample containing a single outlier. Ballot theorem, its generalization, extension and application to fluctuations of sums of random variables. Concepts of record values and generalized order statistics.

Suggested Readings:

1. Arnold, B. C., Balakrishnan, N. and Nagaraja H. N. (2008). A First Course in Order Statistics, SIAM Publishers.
2. Arnold, B.C. and Balakrishnan, N. (1989). Relations, Bounds and Approximations for Order Statistics, Vol. 53, Springer-Verlag.
3. Ahsanullah, M., Nevzorav, V.B. and Shakil, M. (2013). An Introduction to Order Statistics, Atlantis Studies in Probability and Statistics, Vol. III. Atlantis Press.
4. David, H. A. and Nagaraja, H. N. (2003). Order Statistics, 3rd ed., John Wiley & Sons.
5. Gibbons, J.D. and Chakraborti, S. (1992). Nonparametric Statistical Inference, 3rd ed., Marcel Dekker.
6. Shahbaz, M. Q., Ahsanullah, M., Shahbaz, S. H. and Al-Zahrani, B. M. (2016). Ordered Random variables: Theory and Applications. Springer.
7. Takacs, L. (1967). Combinatorial Methods in the Theory of Stochastic Processes, John Wiley & Sons.

Teaching Plan:

Week 1-2 : Introduction to order statistics. Basic distribution theory. Joint and marginal distributions of order statistics in the continuous case. Distribution of the range and other systematic statistics.

Week 3-4 : Conditional distributions. Order statistics as a Markov Chain. Order statistics for a discrete parent. Examples based on discrete and continuous distributions.

Week 5-6: Distribution-free confidence intervals for population quantiles and distribution-free tolerance intervals. Distribution-free bounds for moments of order statistics and of the range. Approximations to moments in terms of the quantile function and its derivatives.

Week 7-8: Moments of order statistics. Recurrence relations and identities for moments of order statistics from an arbitrary distribution.

Week 9-10: Recurrence relations for moments of order statistics from some specific distributions. Large sample approximations to mean and variance of order statistics. Asymptotic distributions of order statistics.

Week 11-12: Order statistics for independently and not identically distributed (i.ni.d.) variates. Order statistics for dependent variates. Concomitants of order statistics. Random division of an interval and its applications.

Week 13-14: Order statistics from a sample containing a single outlier. Ballot theorem, its generalization, extension and application to fluctuations of sums of random variables. Concepts of record values and generalized order statistics.

List of Practicals:

1. Distribution of sample range and other systematic statistics in sampling from different distributions.
2. Conditional distribution of order statistics in sampling from different distributions.
3. Distribution-free confidence intervals for population quantiles for various distributions.
4. Calculating exact moments of order statistics by using recurrence relations for various distributions.
5. Means, variances and covariances of concomitants of order statistics for various bivariate distributions.

6. Calculation of bias and mean square error of various estimators of population mean μ of normal distribution for different sample sizes in the presence of single outlier (location-outlier model).
7. Calculation of variance of various estimators of population mean μ of normal distribution for different sample sizes in the presence of single outlier (scale-outlier model).

MSTE 403 - 404 (iii): Bayesian Inference

Course Objectives: The objective of this course is to provide the understanding of the fundamentals of Bayesian inference including concept of subjectivity and priors by examining some simple Bayesian models and linear regression in a Bayesian framework.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Treat "evidence" as value of observations and prescribe methods to deal rationally with it.
2. Equip students with skills to carry out and interpret posterior and preposterior data based modeling and analyses.
3. Compute probability that the theory in question could produce the observed data.
4. Examine some simple Bayesian models and linear regression in a Bayesian framework.

Unit I: Review of Basic Probability Concepts. Comparing Likelihood and Bayesian Approaches, Concept of Inverse Probability and Bayes Theorem. Classes of Prior Distributions. Conjugate Families for One Parameter Exponential Family Models, Models admitting sufficient statistics of fixed dimension.

Unit II: Generalized Maximum Likelihood Estimate. Types of Loss Functions. Bayes estimation under various loss functions. Posterior Risk. Bayesian interval estimation: Credible intervals, HPD intervals, Comparison with classical confidence intervals. Situation specific case studies to conduct posterior analysis.

Unit III: Prior and posterior odds. Bayes factor. Lindley's Paradox. Various types of testing hypothesis problems.

Unit IV: Predictive density function, Regression Models.

Suggested Readings:

1. Aitchison, J. and Dunsmore, I.R. (1975). Statistical Prediction Analysis, Cambridge University Press.
2. Box, G.E.P. and Tiao, G.C. (1973). Bayesian Inference in Statistical Analysis, Addison & Wesley.
3. DeGroot, M.H. (1970). Optimal Statistical Decisions, McGraw Hill.
4. Leonard, T. and Hsu, J.S.J. (1999). Bayesian Methods, Cambridge University Press.
5. Lee, P. M. (1997). Bayesian Statistics: An Introduction, Arnold Press.
6. Robert, C.P. (2001). The Bayesian Choice: A Decision Theoretic Motivation, 2^{nd} ed., Springer Verlag.

Teaching Plan:

Week 1 : Review of Basic Probability Concepts. Comparing Likelihood and Bayesian Approaches, Concept of Inverse Probability and Bayes Theorem.

Week 2-3 : Classes of Prior Distributions. Conjugate Families for One Parameter Exponential Family Models.

Week 4: Models admitting sufficient statistics of fixed dimension.

Week 5-6: Generalized Maximum Likelihood Estimate. Types of Loss Functions. Bayes estimation under various loss functions. Posterior Risk.

Week 7: Bayesian interval estimation: Credible intervals, HPD intervals, Comparison with classical confidence intervals.

Week 8: Situation specific case studies to conduct posterior analysis.

Week 9-10: Prior and posterior odds. Bayes factor. Lindley's Paradox.

Week 11-12: Various types of testing hypothesis problems.

Week 13-14: Predictive density function, Regression Models.

List of Practicals:

1. Summarizing and Graphing Probability Distributions in R.
2. Confidence and Bayesian intervals.
3. Hypothesis Testing.
4. Posterior Predictive Probabilities.

MSTE 403-404 (iv): Advanced Survey Sampling Theory

Course Objectives: The objective of this course is to provide advanced techniques in survey sampling with practical applications in daily life and to provide accessible statistical tool for applying sampling strategies and methodologies.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Understand the non –existence of uniform estimators and repetitive surveys.
2. Apply the re-sampling techniques for variance estimation – independent and dependent random groups.
3. Understand the design based estimation procedures and double sampling technique for stratification.
4. Understand the response and non- response techniques; Randomized Response Technique and a technique to predict non observed residue under design and model based model.
5. Understand the model assisted sampling strategies; super population model.

Unit I: Admissibility of Estimators; Non-existence of UMV estimators; Estimation of Median; Sampling on two or more successive occasions (Repetitive surveys); Re-Sampling techniques for variance estimation-independent and dependent random groups, the Jackknife and the Bootstrap.

Unit II: Small-area estimation; Design-based conditional approach; Double sampling for stratification.

Unit III: Non-sampling errors; Non-response and missing data; Randomized Response Techniques for one quantitative sensitive characteristic. Prediction of non-observed residual under fixed (design-based) and super-population (model-based) approaches.

Unit IV: Model-assisted sampling strategies; Different types of Super-population models with optimal strategies based on them; Robustness against model failures.

Suggested Readings:

1. Cassel, C.M., Sarndal, C-E and Wretman, J.H. (1977). Foundations of Inference in Survey Sampling, John Wiley & Sons.
2. Chaudhari, A. and Stenger, H. (2005). Survey sampling Theory and Methods, 2nd ed., Chapman and Hall.
3. Hedayat, A.S. and Sinha, B.K. (1991). Design and Inference in Finite Population Sampling, John Wiley & Sons.
4. Muhopadhyay, P. (2007). Survey Sampling, Nerosa Publishing House, New Delhi.
5. Mukhopadhyay, P. (1996). Inferential Problems in Survey Sampling, New Age International (P) Ltd.
6. Levy, P.S. And Lemeshow, S. (2008). Sampling of Populations-Methods and Applications, John Wiley & Sons.
7. Sarndal, C.E., Swensson, B. and Wretman, J.H. (1992). Model Assisted Survey Sampling, Springer-Verlag.
8. Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984). Sampling Theory of Surveys with Applications, Iowa State University Press, Iowa, USA.
9. Wolter, K.M. (2007). Introduction to Variance Estimation, Springer-Verlag.

Teaching Plan:

Week 1-2 : Admissibility of Estimators; Non-existence of UMV estimators; Estimation of Median.

Week 3 : Sampling on two or more successive occasions (Repetitive surveys).

Week 4-5: Re-Sampling techniques for variance estimation-independent and dependent random groups, the Jackknife and the Bootstrap.

Week 6-7: Small-area estimation; Design-based conditional approach; Double sampling for stratification.

Week 8: Non-sampling errors; Non-response and missing data; Randomized Response Techniques for one quantitative sensitive characteristic.

Week 9-10: Prediction of non-observed residuum under fixed (design-based) and super-population (model-based) approaches.

Week 11: Model-assisted sampling strategies.

Week 12-13: Different types of Super-population models with optimal strategies based on them.

Week 14: Robustness against model failures.

List of Practicals:

1. Re- sampling technique: estimation of variance.
2. Randomised Response Technique: estimation of parameters.
3. Estimation of mean and variance under fixed (design-based) approaches.

MSTE 403-404 (v): Advanced Theory of Experimental Designs

Course Objectives: The main objective of this course is to equip students to apply experimental design techniques in real world problems and in research.

Course Learning Outcomes:

After successful completion of this course, student will be able to:

1. Understand the design and analysis of Partially Balanced Incomplete Block Designs and apply them in situations where balanced designs are not available.
2. Construct Hadamard matrices, symmetric and asymmetric orthogonal arrays. Orthogonal arrays are used in industrial setups like automobile industry, computer experiments, cryptography, and quality improvement.
3. Understand the concepts in general theory of Fractional Factorial Experiments and Various optimality criteria to obtain optimal designs.
4. Apply techniques of Response surface methodology, construct designs for first and second order models, and appreciate the concepts of orthogonality, rotatability and blocking.
5. Construct and analyse designs for mixture experiments that are useful in our day to day life, food industry, chemical industry, pharmaceutical companies.
6. Understand and apply Crossover designs in practical situations.
7. Understand the Robust Parameter designs and their use in quality improvement.

Unit I: Partially balanced incomplete block designs, Resolvable and affine resolvable designs, Lattice Designs, Construction of PBIB designs.

Unit II: General Theory of Fractional Factorial Experiments, Optimal designs- Various optimality criteria, Symmetric and asymmetric orthogonal arrays and their constructions.

Unit III: Response surface designs for first and second order models, concepts of orthogonality, rotatability and blocking.

Unit IV: Mixture Experiments–models and designs, Cross-over designs, Robust Parameter designs.

Suggested Readings:

1. Bose, M. and Dey, A. (2009). Optimal Crossover Designs, World Scientific.
2. Cornell, John A. (2002). Experiments with Mixtures, John Wiley & Sons.
3. Dey, A. and Mukerjee, R. (1999). Fractional Factorial Plans, John Wiley & Sons.
4. Das, M. N. and Giri, N. C. (1986). Design and Analysis of Experiments, Wiley Eastern Limited.
5. Dey, A. (1986). Theory of Block Designs, John Wiley & Sons.
6. Hinkelmann, K. and Kempthorne, O. (2005). Design and Analysis of Experiments, Vol. II: Advanced Experimental Design, John Wiley & Sons.
7. Hedayat, A. S., Sloane, N. J.A. and Stufken, J. (1999). Orthogonal Arrays: Theory and Applications, Springer.
8. Jones, B. and Kenward, M.G. (2003). Design and Analysis of Cross-over Trials. Chapman & Hall/CRC Press.
9. Montgomery, D. C. (2005). Design and Analysis of Experiments, Sixth Edition, John Wiley & Sons.
10. Myers, R. H. and Montgomery, D. C. (2002). Response Surface Methodology: Process and Product Optimization using Designed Experiments, John Wiley & Sons.
11. Raghavarao, D. (1970). Construction and Combinatorial Problems in Design of Experiments, John Wiley & Sons.
12. Wu, C. F. J. and Hamada, M. (2000). Experiments: Planning, Analysis and Parameter Design Optimization, John Wiley & Sons.

Teaching Plan:

Week 1-2 : Association schemes, partially balanced incomplete block designs, relationships among parameters.

Week 3-4 : P.B.I.B. (2) designs, analysis, resolvable and affine resolvable designs, Lattice Designs, Construction of PBIB designs.

Week 5-6: Kronecker product of matrices, Hadamard matrices and their constructions, Symmetric and asymmetric orthogonal arrays and their constructions.

Week 7-8: General Theory of Fractional Factorial Experiments, Optimal designs-

Various optimality criteria.

Week 9-11: Response surface designs for first and second order models, concepts of orthogonality, rotatability and blocking.

Week 12-14: Mixture Experiments –models and designs, Cross-over designs, Robust Parameter designs.

List of Practicals:

Practicals based on:

1. PBIB (2) designs.
2. Construction of Hadamard matrices.
3. Construction of orthogonal arrays.
4. Fractional factorial designs.
5. Construction of optimal design.
6. Response surface designs.
7. Mixture designs.
8. Cross-over designs.
9. Robust Parameter designs.

MSTE 403 - 404 (vi): Advanced Statistical Computing and Data Mining

Course Objective: The main objective of this paper is to introduce some advanced statistical computing techniques to extract information, visualization and knowledge about various industries.

Course Learning Outcome:

After successful completion of this course, student will be:

1. Equipped with different theoretical methods and practicable techniques 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 I: Random number generation: Review; Simulating multivariate distributions; Simulating stochastic processes. Stochastic differential equations: introduction, Numerical solutions. Monte Carlo Integration; Variance reduction methods.

Unit II: Markov Chain Monte Carlo methods: The Metropolis–Hastings Algorithm; Gibbs sampling. EM algorithm. Smoothing with kernels: density estimation, choice of kernels.

Unit III: Review of classification methods from multivariate analysis; classification and decision trees. Clustering methods from both statistical and data mining viewpoints; Vector quantization. Unsupervised learning; Supervised learning.

Unit IV: Artificial neural networks: Introduction, multilayer perceptron network, self-organizing feature map and radial basis function network. Structural risk minimization, Introduction to support vector machine. Overview of current applications.

Suggested Readings:

1. Bishop, C.M. (1995) Neural Networks for pattern Recognition, Oxford University Press.
2. Duda, R.O., Hart, P.E. and Strok, D.G. (2000) Pattern Classification, 2nd ed., John Wiley & Sons.
3. Hastie, T., Tibshirani, R., Friedman, J. (2008) The Elements of Statistical Learning: Data Mining, Inference and Prediction, 2nd ed., Springer.

4. Han, J. and Kamber, M. (2000). Data Mining: Concepts and Techniques, Morgan Kaufmann.
5. Haykin, S. (1998) Neural Networks: A Comprehensive Foundation, 2^{nd} ed., Prentice Hall.
6. Hand, D., Mannila, H., and Smyth, P. (2001). Principles of Data Mining, MIT Press.
7. McLachlan, G.J. and Krishnan, T. (1997). The EM Algorithms and Extensions, John Wiley & Sons.
8. Nakhaeizadeh, G. and Taylor G.C., (1997). Machine Learning and Statistics, John Wiley & Sons.
9. Pooch, Udo W. and Wall, James A. (1993). Discrete Event Simulation (A practical approach), CRC Press.
10. Rubinstein, R.Y. (1981). Simulation and the Monte Carlo Method, John Wiley & Sons.
11. Robert, C.P. & Casella, G. (2004) Monte Carlo Statistical Methods, 2^{nd} ed., Springer.
12. Voss, J. (2014). An introduction to statistical computing: a simulation-based approach, Wiley series in computational statistics.

Teaching Plan:

Week 1: Random number generation: Review; Simulating multivariate distributions; Simulating stochastic processes.

Week 2: Stochastic differential equations: Introduction, Numerical solutions.

Week 3: Monte Carlo Integration; Variance reduction methods.

Week 4: Markov Chain Monte Carlo methods: The Metropolis–Hastings Algorithm;

Week 5-6: Gibbs sampling. EM algorithm. Smoothing with kernels: density estimation, choice of kernels.

Week 7-8: Review of classification methods from multivariate analysis; classification and decision trees.

Week 9: Clustering methods from both statistical and data mining viewpoints; Vector quantization.

Week 10: Unsupervised learning; Supervised learning.

Week 11: Artificial neural networks: Introduction, multilayer perceptron network.

Week 12: Self-organizing feature map and radial basis function network.

Week 13: Structural risk minimization, Introduction to support vector machine.

Week 14: Overview of current applications.

List of Practicals:

1. Simulation – Multivariate distribution.
2. Simulation – Stochastic processes.
3. SDE – Numerical solution.
4. Monte Carlo Integration; Variance reduction methods.
5. EM algorithm application.
6. Classification problem application.
7. Clustering problem application.

MSTP 405:- Practical – IV

Part A: Problem Solving using R Software-II

Part B: Problem Solving using SPSS-II

List of Practicals:

1. Practicals on indices of fertility, mortality, life- table construction, population growth models, population projection by means of Leslie matrix.
2. Practicals on control charts, CUSUM chart, tabular CUSUM chart, V- Mask technique, various sampling inspection techniques.
3. To construct $\bar{X}$ and R chart in order to determine whether the production process is working under control or not.
4. To construct p-chart that is fraction defective chart.
5. Plot of AOQ, ASN, ATI and OC curve and obtain AOQL.
6. To obtain C chart for the data.
7. Compute life tables.
8. Find GFR, ASFR, TFR and NRR from the data.
9. Compute CBR, CDR, GFR, TFR and GRR from the table.
10. Estimate mean survival time and reliability.
11. To estimate the trend component using a moving average method in an additive model of time series.
12. To decompose time series model into the 4 additive components, trend, seasonal, cyclical and residual.
13. To identify order of time series model, MA (1) process, using sample correlogram and sample partial correlogram.

14. To identify order of time series model, AR (1) process, using sample correlogram and sample partial correlogram.
15. To fit a multiple regression model and test significance of regression coefficients.
16. Fit Cobb-Douglas production function.
17. Test for the autocorrelation in data using Durbin Watson test.
18. Test for the heteroscedasticity in data using Park's test.

OPEN ELECTIVE COURSES

MSTOE 306 (i): Data Analysis Using R

Course Objectives:

The main objectives of this course are:

1. To learn the principles and methods of data analysis.
2. To provide a basic understanding of methods of analysing data from different fields.
3. To learn R software.

Course Learning Outcomes:

After successful completion of this course, the students will be able to:

1. Carry out data analysis using R software.
2. Effectively visualize and summarize the data.
3. Interpret the results of statistical analysis.

UNIT I: Introduction to R: Installing R, R console, Script file, Workspace, Getting help, R packages, Installing and loading packages. R data structures: vectors, matrices, array, data frames, factors, lists. Creating datasets in R, Importing and exporting dataset, annotating datasets.

Graphs: Creating and saving graphs, customizing symbols, lines, colors and axes, combining multiple graphs into one, bar plots, boxplot and dot plots, pie chart, stem and leaf display, histogram and kernel density plots.

Data management: Manipulating dates and missing values, understanding data type conversion, creating and recoding variables, sorting, merging and sub-setting data sets.

Mathematical and statistical functions, character functions, looping and conditional statements, user defined functions.

UNIT II: Basic statistics: Descriptive statistics, frequency and contingency tables, outlier detection, testing of normality, basics of statistical inference in order to understand hypothesis testing, p-value and confidence intervals.

Parametric tests: Tests for population mean and variance for two or more populations, tests for independence and measures of association, sample size determination for common statistical methods using *pwr* package. Nonparametric tests.

UNIT III: Correlation: Correlations between quantitative variables and their associated significance tests. Regression Analysis: Fitting simple and multiple regression models, forward, backward and stepwise regression, polynomial regression, regression diagnostics to assess the statistical assumptions, methods for modifying the data to meet these assumptions more closely, selecting a final regression model from many competing models.

ANOVA: Fitting and interpreting ANOVA type models, evaluating model assumptions, basic experimental designs: CRD, RBD, LSD and factorial experimental designs.

UNIT IV: Time series Analysis: Creating and manipulating a time series, Components of a time series, auto-correlation and partial correlation function, estimating and eliminating the deterministic components of a time series.

Developing Predictive Models: Forecasting using exponential models, predictive accuracy measures for time-series forecast, testing for stationarity, Forecasting using ARMA and ARIMA models.

Suggested Readings:

1. Kabacoff, R.I. (2015). R in Action: Data Analysis and Graphics in R, 2nd ed., Manning Publications.
2. Davies, T. M. (2016). The Book of R: A First Course in Programming and Statistics, No Starch Press, San Francisco.
3. Crawley, M.J. (2013). The R Book, 2nd ed., John Wiley.
4. Field, A., Miles, J. and Field, Z. (2012). Discovering Statistics using R, Sage, Los Angels.

Teaching Plan:

Week 1-2: Introduction to R: Installing R, R console, Script file, Workspace, Getting help, R packages, Installing and loading packages. R data structures: vectors, matrices, array, data frames, factors, lists. Creating datasets in R, Importing and exporting dataset, annotating datasets.

Graphs: Creating and saving graphs, customizing symbols, lines, colors and axes, combining multiple graphs into one, bar plots, boxplot and dot plots, pie chart, stem and leaf display, histogram and kernel density plots.

Week 3-4: Data management: Manipulating dates and missing values, understanding data type conversion, creating and recoding variables, sorting, merging and sub-setting data sets.

Mathematical and statistical functions, character functions, looping and conditional statements, user defined functions.

Week 5-6: Basic statistics: Descriptive statistics, frequency and contingency tables, outlier detection, testing of normality, basics of statistical inference in order to understand hypothesis testing, computing p-value and confidence intervals.

Week 7- 8: Parametric tests: Tests for population mean and variance for two or more populations, tests for independence and measures of association, sample size determination for common statistical methods using *pwr* package. Nonparametric tests.

Week 9-10: Correlation: Correlations between quantitative variables and their associated significance tests. Regression Analysis: Fitting simple and multiple regression models, forward, backward and stepwise regression, polynomial regression, regression diagnostics to assess the statistical assumptions, methods for modifying the data to meet these assumptions more closely, selecting a final regression model from many competing models.

Weeks 11: ANOVA: Fitting and interpreting ANOVA type models, evaluating model assumptions, basic experimental designs: CRD, RBD, LSD and factorial experimental designs.

Week12-14: Creating and manipulating a time series, Components of a time series, auto-correlation and partial correlation function, estimating and eliminating the deterministic components of a time series.

Developing Predictive Models: Forecasting using exponential models, predictive accuracy measures for time-series forecast, testing for stationarity, Forecasting using ARMA and ARIMA models.

MSTOE 306 (ii): Computational Techniques

Course Objectives: The main objective of this course is to allow the students to learn the advanced techniques of modeling real data from diverse discipline.

Course Learning Outcomes:

After successful completion of this course, the students will be able to:

1. Simulate statistical models.
2. Understand linear models and distinguish between fixed, random and mixed effects models.
3. Learn and apply regression technique in their area of study.
4. Understand and apply time series models.

Unit I: Probability Distributions: Bernoulli, Binomial, Poisson, Multinomial, Uniform, Exponential, Gamma, Beta, Normal, Chi Square, t and F distribution.

Simulation: Random number generation, simulating statistical models, Monte Carlo Methods.

Unit II: Linear Models: Fixed, random and mixed effects models, ANOVA: one way and two way, ANOCOVA.

Regression Models: Simple and Multiple Linear Regression, Forward, Backward and stepwise regression, Residual analysis.

Diagnostics and tests for violations of model assumptions: Multicollinearity, Autocorrelation and Homoscedasticity.

Unit III: Generalized Linear Model: Exponential family of distributions, Link function, Canonical link Function, deviance, Logit and Probit models, Logistic and Poisson regression, ML estimation, Lack of fit tests.

Unit IV: Time Series: Stationary and Nonstationary time series, Autocorrelation and Auto-covariance functions and their properties, Tests for trend and seasonality.

Stationary processes: Moving average (MA) process, Auto-regressive (AR) process, ARMA, ARIMA and SARIMA models. Box-Jenkins model, Estimation of mean, auto-covariance and auto-correlation function under large sample theory. Forecasting: Exponential smoothing methods, Direct smoothing, Adaptive smoothing.

Note: Data analysis and applications of the methods are to be carried out using a statistical package like Excel/R/SPSS/MINITAB/MATLAB or any other.

Suggested Readings:

1. Chatterjee, S. and Hadi, A.S. (2012). Regression Analysis by Example, 5th ed., John Wiley, New Jersey.
2. Fox, J. and Weisberg, S. (2011). An R Companion to Applied Regression, 2nd ed., Sage.

3. Weisberg, S. (2014). Applied Linear Regression, 4th ed., John Wiley,
4. Cryer, J.D. and Chan, K. (2008). Time Series Analysis: With Applications in R, Springer, New York.
5. Montgomery, D.C., Jennings, C.L. and Kulahci, M. (2008). Introduction to Time Series Analysis and Forecasting, John Wiley, New Jersey.
6. Ross, S.M. (2006). Simulation, 4th ed., American Press, USA.
7. Voss, J. (2014). An Introduction to Statistical Computing, John Wiley.
8. Kroese, D.P. and Chan, J.C.C. (2014). Statistical Modeling and Computation, Springer.
9. Agresti, A. (2015). Foundations of Linear and Generalized Linear Models, John Wiley, New Jersey.
10. Montgomery, D.C. (2001). Designs and Analysis of Experiments, John Wiley & Sons, New York.

Teaching Plan:

Week 1: Probability Distributions: Bernoulli, Binomial, Poisson, Multinomial, Uniform, Exponential, Gamma, Beta, Normal, Chi Square, t and F distribution.

Week 2-3: Simulation: Random number generation, simulating statistical models, Monte Carlo Methods.

Week 4-5: Linear Models: Fixed, random and mixed effects models, ANOVA: one way and two way, ANOCOVA.

Week 6-7: Regression Models: Simple and Multiple Linear Regression, Forward, Backward and stepwise regression, Residual analysis.
Diagnostics and tests for violations of model assumptions: Multi-co-linearity, Autocorrelation and Homoscedasticity.

Week 8-10: Generalized Linear Model: Exponential Family of distributions, Link function, Canonical link Function, deviance, Logit and Probit models, Logistic and Poisson regression, ML estimation, Lack of fit tests.

Week 11: Time Series: Stationary and nonstationary time series, Autocorrelation and Auto-covariance functions and their properties, Tests for trend and seasonality.

Week 12-14: Stationary processes: Moving average (MA) process, Auto-regressive (AR) process, ARMA, ARIMA and SARIMA models. Box-Jenkins model, Estimation of mean, auto-covariance and auto-correlation function under large sample theory. Forecasting: Exponential smoothing methods, Direct smoothing, Adaptive smoothing.

MSTOE 306 (iii): Essentials of Survey Sampling and Experimental Designs

Course Objectives:

The main objectives of this course are:

1. To learn the methods of conducting a sample survey.
2. To learn how to design and conduct an experiment.
3. To analyse and interpret the results of a designed experiment.

Course Learning Outcomes:

After completing this course, the students will be able to:

1. Plan and conduct a sample survey.
2. Choose a proper sampling design for conducting a sample survey.
3. Understand the need of a designed experiment.
4. Understand basic designs and apply them in their area of study.
5. Analyse and interpret the results.

Unit I: Population and sample, survey process, survey design, frame, different types of data collection methods, advantages and disadvantages, online surveys, designing survey questions and questionnaires, ordering of questions, open verses closed questions, errors in sample survey, planning a survey.

Detection and correction of errors in survey data: Nonresponse and its effect, methods to reduce nonresponse, correction techniques, imputation techniques and their effects on the properties of estimator.

Unit II: Random number tables, methods of sample selection and estimation with their properties – simple random sampling (with and without replacement), stratified sampling, cluster sampling, ratio and regression estimation and selection with probability proportional to sizes.

Unit III: Gauss Markov linear model, estimable functions, least squares estimators and their properties, regression analysis, ANOVA and ANOCOVA.

Unit IV: Basic concepts, basic principles, uniformity trial, error control, determination of optimal plot size, simple and complex (or factorial) experiments, Design and Analysis of Experiments: Basic designs, missing plot techniques, balanced incomplete block designs, split plot designs.

Suggested Readings:

1. Bethlehem, J. (2009). Applied Survey Methods: A Statistical Perspective, John Wiley, New Jersey.
2. Cochran, W.G. (2011).Sampling Techniques, 3rd ed., Wiley Eastern John Wiley and Sons.
3. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005). Fundamentals of Statistics,Vol. II, 8th ed., World Press, Kolkata.
4. Montgomery, D.C. (2001). Designs and Analysis of Experiments, John Wiley and Sons, New York.
5. Murthy M.N. (1977). Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
6. Mukhopadhyay, P. (1998). Theory and Methods of Survey Sampling, Prentice Hall of India.
7. Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Ashok, C. (1984). Sampling Theory of Surveys with Applications, Lowa State University Press, Lowa, USA.
8. Scheaffer, R.L., Mendenhall, W., Ott, R.L. and Gerow, K. (2012). Elementary Survey Sampling, 7th ed., Cengage Learning.

Teaching Plan:

Week 1-2: Population and sample, survey process, survey design, frame, different types of data collection methods, advantages and disadvantages, online surveys, designing survey questions and questionnaires, ordering of questions, open verses closed questions, errors in sample survey, planning a survey.

Week 3: Detection and correction of errors in survey data: Nonresponse and its effect, methods to reduce nonresponse, correction techniques, imputation techniques and their effects on the properties of estimator.

Week 4-7: Introduction, random number tables, methods of sample selection and estimation with their properties – simple random sampling (with and without replacement), stratified sampling, cluster sampling, ratio and regression estimation and selection with probability proportional to sizes.

Week 8: Gauss Markov model, estimability, BLUE, simple and multiple regression.

Week 9: ANOVA for one and two way classified data under fixed and random effects models.

Week 10: ANOCOVA for one and two way classified data under fixed and random effects model.

Week 11: Basic concepts, basic principles, uniformity trials, error control, determination of optimum plot size.

Week 12: Simple vs complex (or factorial) experiments, confounding.

Week 13: Basic designs, Missing plot techniques.

Week 14: Balanced incomplete block designs, Split plot designs.

MSTOE 306 (iv): Actuarial Statistics

Course Objectives:

The main objectives of this course are:

1. To learn the basic concepts and statistical methods used in actuarial science.
2. To provide an exposure to the basic models of insurance processes.

Course Learning Outcomes:

After completing this course, the students will be able to:

1. Understand the basic actuarial models.
2. Apply the methods of actuarial science in insurance and risk management.

UNIT I: Actuarial science: an overview, Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions, risk and insurance, insurance products, reinsurance and its different types. Utility theory: Utility functions, expected value principle, expected utility criterion, types of utility function, insurance and utility theory.

UNIT II: Principles of Premium Calculation: Properties of premium principles, premium principles. Individual risk models: models for aggregate claims, sum of independent claims, approximations and their applications. Collective risk models: Models for aggregate claims, compound Poisson distribution and its properties.

UNIT III: Survival Distribution and Life Tables: Age at death random variable, survival function, time until-death for a person, curate future lifetime, force of mortality, life tables, relation of life table functions to the survival function, deterministic and random survivorship group, life table characteristics, recursion formulas, assumptions for fractional age, analytical laws of mortality, select and ultimate tables.

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding, present value of a future payment.

UNIT IV: Life Insurance models: Models for insurance payable at the moment of death and at the end of the year of death - level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance. Life annuities: Various forms of annuities, continuous life annuities, discrete life annuities, life annuities with m-thly payments. Premiums: Loss at issue random variable, continuous and discrete premiums, gross premiums.

Suggested Readings:

1. Dickson, C. M. D. (2005). Insurance Risk and Ruin (International Series no.1 Actuarial Science), Cambridge University Press.
2. Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J. (1997). Actuarial Mathematics. Society of Actuaries, Itasca, Illinois, U.S.A.
3. Rotar, V.I. (2015). Actuarial Models: The Mathematics of Insurance, 2nd ed., CRC Press, New York.
4. Deshmukh, S.R. (2009). Actuarial Statistics: An Introduction Using R, University Press, India.

Teaching Plan:

Week 1: Actuarial science: an overview, Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions, risk and insurance, insurance products, reinsurance and its different types.

Week 2- 3: Utility theory: Utility functions, expected value principle, expected utility criterion, types of utility function, insurance and utility theory.

Weeks 4- 5: Principles of Premium Calculation: Properties of premium principles, premium principles. Individual risk models: models for aggregate claims, sum of independent claims, approximations and their applications.

Weeks 6: Collective risk models: Models for aggregate claims, compound Poisson distribution and its properties.

Weeks 7- 9: Survival Distribution and Life Tables: Age at death random variable, survival function, time until-death for a person, curate future lifetime, force of mortality, life tables, relation of life table functions to the survival function, deterministic and random survivorship group, life table characteristics, recursion formulas, assumptions for fractional age, analytical laws of mortality, select and ultimate tables.

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding, present value of a future payment.

Weeks 10-11:	Life Insurance models: Models for insurance payable at the moment of death and at the end of the year of death - level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance.
Weeks 12-13:	Life annuities: Various forms of annuities, continuous life annuities, discrete life annuities, life annuities with m-thly payments.
Week 14:	Premiums: Loss at issue random variable, continuous and discrete premiums, gross premiums.

MSTOE 306 (v): Inferential Techniques

Course Objectives: To make students aware of estimation (point, as well as, interval) and 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 estimation and testing procedures to deal with real life problems.
2. Understand nonparametric methods.
3. Understand Neyman-Pearson fundamental lemma, UMP test, Interval estimation and confidence interval.

Unit I: Minimal sufficiency and ancillarity, Exponential families and Pitman families, Invariance property of Sufficiency under one-one transformations of sample and parameter spaces. Fisher Information for one and several parameters models. Lower bounds to variance of estimators, necessary and sufficient conditions for MVUE.

Unit II: Neyman-Pearson fundamental lemma and its applications, UMP tests for simple null hypothesis against one-sided alternatives and for one-sided null against one-sided alternatives in one parameter exponential family. Extension of these results to Pitman family when only upper or lower end depends on the parameters and to distributions with MLR property.

Unit III: Non-existence of UMP tests for simple null against two-sided alternatives in one parameter exponential family. Families of distributions with monotone likelihood ratio and UMP tests.

Unit IV: Non- parametric methods-estimation and confidence interval, U-statistics and their asymptotic properties, UMVU estimator, nonparametric tests-single sample location, location-cum-symmetry, randomness and goodness of fit problems; Rank order statistics, Linear rank statistics, Asymptotic relative efficiency.

Suggested Readings:

1. Bartoszynski, R. and Bugaj, M.N. (2007). Probability and Statistical Inference, John Wiley & Sons.
2. Ferguson, T.S. (1967). Mathematical Statistics, Academic Press.
3. Kale, B.K. (1999). A First Course on Parametric Inference, Narosa Publishing House.
4. Lehmann, E.L. (1986). Theory of Point Estimation, John Wiley & Sons.
5. Lehmann, E.L. (1986). Testing Statistical Hypotheses, John Wiley & Sons.
6. Rohatgi, V.K. and Saleh, A.K. Md. E. (2005). An Introduction to Probability and Statistics, 2nd Edn., John Wiley& Sons.
7. Rao, C.R. (1973). Linear Statistical Inference and Its Applications, 2^{nd} ed., Wiley Eastern Ltd., New Delhi.
8. Zacks, S. (1971). Theory of Statistical Inference, John Wiley & Sons.
9. Gibbons, J.D. and Chakraborti, S. (1992). Nonparametric Statistical Inference, Marcel Dekker.
10. Randles, R.H. and Wolfe, D.S. (1979). Introduction to the Theory of Non-parametric Statistics, John Wiley & Sons.

Teaching Plan:

Week 1-2 : Minimal sufficiency and ancillarity.

Week 3 : Exponential families and Pitman families.

Week 4: Invariance property of Sufficiency under one-one transformations of sample and parameter spaces.

Week 5: Fisher Information for one and several parameters models.

Week 6: Lower bounds to variance of estimators, necessary and sufficient conditions for MVUE.

Week 7: Neyman-Pearson fundamental lemma and its applications.

Week 8: UMP tests for simple null hypothesis against one-sided alternatives and for one-sided null against one-sided alternatives in one parameter exponential family.

Week 9: Extension of these results to Pitman family when only upper or lower end depends on the parameters and to distributions with MLR property.

Week 10: Non-existence of UMP tests for simple null against two-sided alternatives in one parameter exponential family.

Week 11: Families of distributions with monotone likelihood ratio and UMP tests.

Week 12: Non- parametric methods-estimation and confidence interval, U-statistics and their asymptotic properties.

Week 13: UMVU estimator, nonparametric tests-single sample location, location-cum-symmetry, randomness and goodness of fit problems; Rank order statistics.

Week 14: Linear rank statistics, Asymptotic relative efficiency.

MSTOE 306 (vi): Statistics for Research and Management Studies

Course Objectives:

The main objectives of this course are:

1. To learn statistical techniques useful for research work.
2. To understand the quantitative methods used in business and management studies.

Course Learning Outcomes:

After completing this course, the students will be able to:

1. Know different types of data produced in their area of study.
2. Create, manage, visualize, and summarize datasets.
3. Use and understand the inferential procedures.
4. Apply suitable sampling design.
5. Understand and apply basic designs.
6. Apply regression techniques.
7. Get an understanding of multivariate techniques.
8. Apply suitable statistical techniques to analyse the data and interpret the results.

Unit I: Data types, scale of measurement, creating and managing datasets, importing and exporting data, data cleaning. Summarizing data: Frequency and probability distributions, measures of central tendency, measures of dispersion, skewness and kurtosis. Correlation and regression, Measures of association, Cross tabulation. Visualizing data: Histogram, bar chart, pie chart, stem and leaf display, scatter plot, box and whisker plot.

Unit II: Inference: Population and sample, parameter and statistic, estimates and estimators, estimation of parameters, type I and type II errors, p-value, statistical hypotheses, testing of hypothesis, inferences based on sample. Tests based on sampling distributions: Z, t, χ^2 and F, Sample size determination.

Sampling Techniques: Simple random sampling, Stratified random sampling, Multi-stage sampling, Cluster Sampling, Systematic sampling.

Unit III: ANOVA for one way and two way classification. ANOCOVA, analysis of basic designs, analysis of 2 level factorial experiments. Simple and multiple regression, logistic regression.

Unit IV: Idea of multivariate data, Variance-Covariance matrix, Testing based on mean vector and variance-covariance matrix, principal component analysis, factor analysis, discriminant analysis, cluster analysis, canonical correlation.

Note: Data analysis and applications of the methods are to be carried out using a statistical package like Excel/R/SPSS/MINITAB/MATLAB or any other.

Suggested Readings:

1. Raghavarao, D. (1988). Exploring Statistics, Markel Dekker, New York.
2. Taylor, J.K. and Cihon, C. (2004). Statistical Techniques for Data Analysis, 2nd ed., Chapman & Hall.
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Teaching Plan:

Week 1-3: Data types, scale of measurement, creating and managing dataset, importing and exporting data, data cleaning. Summarizing data: Frequency and probability distributions, measures of central tendency, measures of dispersion, skewness and kurtosis. Correlation and regression, Measures of association, Cross tabulation. Visualizing data: Histogram, bar chart, pie chart, stem and leaf display, scatter plot, box and whisker plot.

Week 4-6: Inference: Population and sample, parameter and statistic, estimates and estimators, estimation of parameters, type I and type II errors, p-value, statistical hypotheses, testing of hypothesis, inferences based on sample. Tests based on sampling distributions: Z, t, χ^2 and F, Sample size determination.

Week 7: Sampling Techniques: Simple random sampling, Stratified random sampling, Multi-stage sampling, Cluster Sampling, Systematic sampling,

Week 8-11: ANOVA for one way and two way classification. ANOCOVA, analysis of basic designs, analysis of 2 level factorial experiments. Simple and multiple regression, logistic regression.

Week12-14: Idea of multivariate data, Variance-Covariance matrix, Testing based on mean vector and variance-covariance matrix, principal component analysis, factor analysis, discriminant analysis, cluster analysis, canonical correlation.