Swami Ramanand Teerth Marathwada University, Nanded
School of Mathematical Sciences

Two Year M. A. / M. Sc. Degree Program in Statistics

Revised Syllabi of M. A. / M. Sc. in Statistics

(Choice Based Credit System)

(To be implemented in the Department of Statistics, Swami Ramanand Teerth Marathwada University, Nanded)

M. A. / M. Sc. in Statistics

(With effect from Academic Year 2016-2017)

Title of the Program: M. A. / M. Sc. in Statistics

1. Preamble: M. A. / M. Sc. Statistics programme is of minimum 100 credits spread over four semesters. The programme emphasizes both theory and applications of statistics and is structured to provide knowledge and skills in depth necessary for the employability of students in industry, other organizations, as well as in academics. The program has some unique features such as independent projects, number of elective courses, extensive computer training of statistical computations including standard software packages such as MATLAB, R, TORA and SPSS. The department has the academic autonomy and it has been utilized to add the new and need based elective courses. The independent project work is one of the important components of this program. In the first year all courses are compulsory. In semester III & IV some courses are compulsory and others are elective. The syllabus has been framed to have a good balance of theory, methods and applications of statistics.

It is possible for the students to study basic courses from other disciplines such as economics, life sciences, computer science and mathematics in place of electives.

2. Introduction: M. A. / M. Sc. Statistics program has semester pattern and credit system with variable credits. The program consists of 100 credits. Credits of a course are specified against the title of the course. A course with T in brackets indicates that it is a theory course whereas a course with P in brackets indicates that it is a practical course. Some of the practical courses are linked with a theory course and in such a case, both the courses will have the same number with T and P, indicating a theory and a practical course respectively. A student can enroll for a practical course if the student has enrolled for the corresponding theory course (as indicated) in the same term.

- **Scope:**

• To cover the basic statistical theory needed by practicing as a statisticians.

• To furnish students to teach themselves new skills in what is a fast developing area under discussion.

• To enable students to turn a problem described in terms into something that can be tackled by a statistical analysis.

• Teach, and provide the opportunities to learn, a core of advanced statistical methods, together with a range of more specialized options in Statistics.

3. The key learning outcomes of the M.Sc. Statistics are:

• The student's can handle and analyze large databases with computer skills.

•The students may able to describe complex statistical ideas to non-statisticians and to present the results of their analyses in written, oral forms and can make practical suggestions for improvement.

• The students may get wide range of opportunities of Statistics in industry sector.

• The students will get wide range of statistical skills, including problem-solving, project work and presentation, they may enable to take prominent roles in a wide spectrum of employment and research.

4. Eligibility: For M. A. / M.Sc. in Statistics following candidates are eligible.

- B. A./ B. Sc. with Statistics/ Mathematics as a principal subject.

5. Definitions:

Credits:

Credit is a kind of weightage given to the contact hours to teach the prescribed syllabus, which is in a modular form. Normally one credit is allocated to 15 contact hours.

- In each of the courses, credits will be assigned on the basis of the number of lectures / tutorials / laboratory work and other forms of learning required for completing the course contents in maximum 18 week schedule.
- The instructional days as worked out by the UGC for one academic year are 180 working days i.e. 90 days per semester.
- **Mechanics of Credit Calculation:** As per SRTMUN standard, 1Credit= 15 contact hours. o Contact hours will include all the modes of teaching like lectures / tutorials / laboratory work / fieldwork or other forms which suits to that particular course. In determining the number of hours of instruction required for a course involving laboratory / field-work, 2 hours of laboratory / field work is generally considered equivalent to 1 hour of lecture.

Credit Point (P):

Credit point is the value obtained by multiplying the grade point (G) by the credit (C): $P = G \times C$.

Grade Point:

Grade point is an integer indicating the numerical *SEMESTER GRADE POINT AVERAGE (SGPA):*

II. Semester Grade Point Average (SGPA) is the value obtained by dividing the sum of credit points (P) earned by a student in various courses taken in a semester by the total number of credits earned by the student in that semester. SGPA shall be rounded off to two decimal places.

II. Cumulative Grade Point Average (CGPA):

'Cumulative Grade Point Average' (CGPA) is the value obtained by dividing the sum of credit points in all the courses earned by a student for the entire programme, by the total number of credits. CGPA shall be rounded off to two decimal places. CGPA indicate an overall letter grade (Cumulative Grade) for the entire programme shall be awarded to a student depending on his/her CGPA. The comprehensive academic performance of a student in a programme is equivalent of the letter grade.

- **Evaluation System -**

In this section the broad guidelines to be followed in evaluation system and the minimum number of credits to be completed to get a degree are defined.

- The evaluation will be on Continuous Internal Assessment (CIA), End Semester Assessment (ESA). The final results shall be declared after integration of CIA and ESA
- Weightage: 50% for End Semester Assessment (ESA) & 50% for Continuous Internal Assessment (CIA)

The declaration of result is based on the grade point average (GPA) earned towards the end of each semester or the Cumulative Grade Point Average (CGPA) earned towards the end of the program.

a) The Post-graduate degree will be awarded to those students who earn the minimum number of Credits. For the award of degree the student has to acquire minimum number of credits as per the table given below.

Name of the Faculty/course	Total credits	Average credits per semester
M.A./ M.Sc.	**100**	**25**

b) One credit will be equivalent to 15 clock hours of teacher-student contact in a semester.

c) Four –credit course of theory will be of four clock hours per week.

d) Two- credit course of practical will be of 4 hours of lab exercise/field.
e) The project / "Dissertation" will be commencing from Semester III and the final work & report will be completed during Semester IV. The marks & the credits will be allotted in semester IV.

f) There will be no mid-way change allowed from Credit System to Non-credit (external) System or vice versa.

g) In a case, where the PG program duration is of one year, such a program shall consist of minimum 50 credits. Certificate programs shall consist of 25 credits/ semester.

h) In a case, where the PG program duration is of three year, such a program shall consist of minimum 150 credits.

i) Except the credits for practical courses, wherever applicable, a student can register for less number of courses in a semester subject to the condition that such a student will have to complete the degree in a maximum of five, four and two years respectively for three, two and one year programs. This facility will be available subject to the availability of concerned courses in a given semester and with a maximum variation of 25 % credits (in case of fresh credits) per semester.

j) CBCS: Among the minimum number of credits to be earned by a student to complete a Post Graduate degree program (100/64 credits), the student will have to earn minimum 75% credits from the core subjects and the remaining 25 % credits could be earned from the elective/ open elective (inter/intra disciplinary and soft skills) subjects offered within and across the schools. The maximum number of credits offered across the disciplinary (including soft skills) should not exceed 10% of total credits for the program.

k) Credit transfer from other Institutes: Depending on the feasibility and availability a maximum of four credits can be completed by the student in any of the national or reputed institutes/organizations/companies/ industries (HOST). For this a student has to complete a minimum number of 15 interactive hours (not necessarily only teaching) with assigned faculty from Host. It may be 3-4 interactive hours in a day and the necessary certificate in this regard shall be issued by HOST faculty. The Director of the school can fix this credit transfer mechanism with mutual consent/understanding form any host institute. After completion of minimum required interactive/teaching hours at the chosen institute the Host has to provide course completion certificate with a grade. The

assessment will be made by the concerned faculty of the host and one faculty/Director of the concerned school (Parent) and performance grade and marks will be allotted. The same marks shall be sent to university examination section along with other marks for declaration of the results by the concerned school.

6. Examination/Evaluation Rules

The evaluation of the student will be mainly on

1. **Continuous Internal Assessment (CIA) and**
2. **End Semester Assessment (ESA).**

The ratio of CIA and ESA is 50:50

Passing Rules:

The CIA and ESA shall have different passing heads and Minimum passing:- 40% of passing for each subject in each head. To pass the degree program, a student will have to obtain a minimum aggregate of 40% marks (C+ and above in grade point scale) in each course.

Assessment:

Continuous Internal Assessment (CIA):

CIA aims to assess values, skills and knowledge imbibed by students, internal assessment is to be done by the concerned faculty member, department, school or the centre. **CIA** will be done on a continuous basis during the semester with selected assessment components.

The components selected for CIA may be:

Tests, Quiz, Seminars, Assignments, essay, tutorials, term paper, seminar, laboratory work, field work, workshop practice, Comprehensive Viva, Attendance and any other best and innovative assessment practice approved by the School committee. Components of internal evaluation are to have a time frame for completion (by students), and concurrent and continuous evaluation (by faculty members).

The evaluation outcome shall be expressed initially by predetermined marks and latter converted by grades. Minimum Mark for passing in each Paper is 40% for Continuous Internal Assessment **(CIA)**

End Semester Assessment (ESA): This is to be carried out at the end of each semester, and will aim to assess skills and knowledge acquired by the students through classroom instruction, fieldwork, laboratory work and/or workshop practice. The End Semester Assessment (ESA) is based on written examination.

These examinations shall be at the end of each semester.

Integration of CIA and ESA: A student failed in CIA shall have to appear for ESA again in that particular paper. In a particular paper if a student failed in internal (CIA), he deemed to be failed in that course and he has to reappear for CIA and ESA irrespective of the marks he got in ESA. If a student passed in CIA and failed in ESA, the student needs to appear for ESA only in his next attempt and the CIA marks shall be carried.

A candidate who does not pass the examination in any course(s) shall be permitted to appear in such failed course(s) in the subsequent examinations to be held in winter/summer season. However the student has to clear the course in the prescribed maximum period for that course.

CIA marks will not change. A student cannot repeat CIA. In case s/he wants to repeat CIA, then s/he can do so only by registering the said course during the semester in which the course is conducted and up to 4 years (2 years program) as the case may be, provided the student was failed in that course. Students who have failed in a course may reappear for the ESA only twice in the subsequent period. If student fail to acquire required Credits within four years from admission period, such student has to acquire Credits with prevailing / revised syllabus at that time. After that, such students will have to seek fresh admission as per the admission rules prevailing at that time.

A student cannot register for the third/fourth semester, if she/he fails to complete 75% credits of the total credits expected to be ordinarily completed within two semesters.

While marks will be given for all examinations, they will be converted into grades. The semester end grade sheets will have only grades and final grade sheets and transcripts shall have grade points average and total percentage of marks (up to two decimal points).

7. Assessment and Grade point average:

7.1 The system of evaluation will be as follows: Each CIA and ESA will be evaluated in terms of marks. The marks for CIA and ESA will be added together and then converted into a grade and later a grade point average.

7.2 Results will be declared for each semester.

7.3 After the completion of minimum number of credits of a program, a student will get a grade sheet with total grades earned and a grade point average.

7.4 Marks/Grade/Grade Point:

i) Table 1: Conversion of marks to grades in credit system

Marks Obtained	Grade	Grade Points
100-90	S	10
89-80	O	09
79-70	A+	08
69-60	A	07
59-55	B+	06
54-45	B	05
44-40	C+	04
39 and Less FC	FC	0 (Fail but Continue)
39 and Less (Internal)	FR	0 (Fail and Repeat the course)

ii) A student who passes the internal tests but fails in Term End Examination of a course shall be given FC grade. Student with FC grade in a course would be granted credit for that course but not the grade for that course and shall have to clear the concerned course within 1.5 year from appearing for first time in the concerned paper, provided the number of courses with FC and FR grades together is 25% or less of the courses of that semester, failing which he/she shall be disqualified for a credit and will have to opt for another credit.

iii) Student who has failed in the internal tests of a course shall be given FR grade and shall have to repeat the concerned course to qualify to appear for term end examination of that course. The grade FC and FR will be taken into consideration while calculating Semester Performance Index (SPI). It shall be replaced only when student clears the course with passing grade within 1.5 year from appearing for first time in the concerned semester.

iv) Grade points earned in each paper shall be calculated as- Grade points obtained (vide Table 1 above) X Credits for the paper.
Maximum grade points that can be earned in a semester are 200.

v) The Semester Performance Index (SPI) gives weighted performance index of a semester with reference to the credits of a course. The SPI shall be calculated as-

SPI = Total Earned Grade Pointes (as given above) for the Semester
Total Credits for the semester

7.5 The total grade point earned in each course shall be calculated as:
Grade point obtained as shown in table -1 **X** Credits for the Course

7.6 Semester Grade Point Average (SGPA): The performance of the student in a semester is indicated by number called SGPA. It shall be calculated as follows:

$$\text{SGPA} = \frac{\sum_{i=1}^{n} c_i p_i}{\sum_{i=1}^{n} c_i}$$

Where C_i = The number of Credits earned in the i^{th} course of a semester for which SGPA is to be calculated.

p_i = Grade point earned in the i^{th} course.

i = 1,2,3,4,……..n represent the number of courses in which a student is registered in the concerned semester.

That is

$$\text{SGPA} = \frac{\text{Total earned grade point for the semester}}{\text{Total credits for the semester}}$$

7.7 Final result:

The final marls after assessment will be submitted by the respective schools to the controller of Examination for finalization of the resuts. Up to date assessment of the overall performance of a student from the time of his / her first registration is obtained by calculating a number is called as Cumulative Grade Point Average (CGPA), which is weighted average of the grade points obtained in all courses registered by the student since he / she entered the department.

$$\text{CGPA} = \frac{\sum_{j=1}^{m} c_j p_j}{\sum_{j=1}^{m} c_j}$$

Where C_j = The number of Credits earned in the j^{th} course up to the semester for which CGPA is to be calculated.

p_j = Grade point earned in the j^{th} course.

j = 1, 2, 3, 4…m represent the number of courses in which a student is registered up to the semester for which the CGPA is to be calculated.

- **Final Grade: Table -2**

CGPA	Grade
09.00-10.00	S: Super
08.00-08.99	O : Outstanding
07.50-07.99	A+: Excellent
07.00-07.49	A: Very Good
06.00-06.99	B+: Good
05.00-05.99	B: Satisfactory
04.00 -04.49	C+: Pass
00.00-03.99	F: Fail

7.8 'B+' Grade is equivalent to at least 55% of the marks as per circular No. UGC- 1298/ [4619] UNI- 4 dated December 11, 1999.

7.9 " A" Grade is equivalent to first class

7.10 If the (C) GPA is higher than the indicated upper limit in the three decimal digit, then higher final grade will be awarded (e.g. a student getting (C)GPA of 3.992 may be awarded 'C+' grade).

7.11 For grade improvement a student has to reappear for End Semester Examination (ESE) after the successful completion of the course for a minimum 20 credits in case of Science, Technology, Management and Pharmacy, 20 credits for other faculties and 12 credits in case of one year degree program. These courses will be from the parent Department (core subject). A student can appear only once for the Grade Improvement Program only after the successful completion of UG / PG Degree program and at the end of the next academic year after completion of the Degree and within two years of completion of the Degree.

7.12 The formula for CGPA will be based on Weighted Average. The final CGPA will not be printed unless a student earns minimum 100 credits, 80 credits or 64 credits, as the case may be, from the courses at UG / PG programs.

7.13 If a student failed to obtain a grade other than F in a course then such a course will not be taken into account for calculating CGPA and overall grade. In fact, all the courses in which a student has passed will be taken into account for calculating the CGPA and overall grade.

8. Norms & Procedure for Extra Credit Benefit for NSS or Participation:

The following table shows the grades along with grade point to be given to the students participating in the NSS / Sports activities:

The student should avail the only one benefit neither from NSS or Sport activities.

Maximum addition of Grade point = 0.200

Sr. No.	Event	Specification	Grade point
1	NSS Performance	2 Year regular Programme [240 hrs work + Blood donation + Camp (State / National Level)]	0.200
2	Sports Performance	Intercollegiate : I /II /III	0.150
		Inter- University : I /II /III or Participation	0.200

9. Structure of the course

M.Sc. (Statistics)-I year (CBCS Pattern)

SEMESTER-I								
Sr. No.	**Course**	**Course Title**	**Theory/ Practical Paper**	**No. of Credits**	**Marks@ 25/Credit**	**Internal Component (50%)**	**Semester End Component (50%)**	**Grand Total**
STT 01	Core I	Real Analysis	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 02	Core II	Linear Algebra	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 03	Core III	Distribution Theory	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 04	Core IV	Sampling Methods	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 05	Core V	Statistical Computing (R Programming)	**L/T**	**4**	**100**	**50**	**50**	**100**
STP 01	Core Practical I	Practical-I (based on STT 02 and STT 05)	**P**	**2**	**50**	**--**	**50**	**50**
STP 02	Core Practical II	Practical-II (based on STT 03 and STT 04)	**P**	**2**	**50**	**--**	**50**	**50**
STS 01	Soft Skill	Soft Skill-I	**L/T/P**	**1**	**25**	**--**	**25**	**25**
		Total						**625**

SEMESTER-II								
Sr. No.	**Course**	**Course Title**	**Theory/ Practical Paper**	**No. of Credits**	**Marks@ 25/Credit**	**Internal Component (50%)**	**Semester End Component (50%)**	**Grand Total**
STT 06	Core VI	Probability Theory	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 07	Core VII	Regression Analysis	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 08	Core VIII	Parametric Inference	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 09	Core IX	Calculus	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 10	Core X	Stochastic Processes	**L/T**	**4**	**100**	**50**	**50**	**100**
STP 03	Core Practical III	Practical-III (based on STT 08 and STT 09)	**P**	**2**	**50**	**--**	**50**	**50**
STP 04	Core Practical IV	Practical-IV(based on STT 07 and STT 10)	**P**	**2**	**50**	**--**	**50**	**50**
STS 02	Soft Skill	Soft Skill-II	**L/T/P**	**1**	**25**	**--**	**25**	**25**
		Total						**625**

M.Sc. (Statistics)-II year (CBCS Pattern)

SEMESTER-III								
Sr. No.	**Course**	**Course Title**	**Theory/ Practical Paper**	**No. of Credits**	**Marks@ 25/Credit**	**Internal Component (50%)**	**Semester End Component (50%)**	**Grand Total**
STT 11	Core XI	Industrial Statistics	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 12	Core XII	Operations Research-I	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 13	Core XIII	Design of Experiments	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 14	Core XIV	Testing of hypotheses	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 15 (A)/(B)	Elective Group I	Time Series Analysis/ Decision Theory/Statistical methods in Finance	**L/T**	**4**	**100**	**50**	**50**	**100**
STP 05	Core Practical III	Practical-V (based on STT 11, STT 12 and STT 14)	**P**	**2**	**50**	**--**	**50**	**50**
STP 06	Core Practical IV	Practical-VI (based on STT 13 and Elective) STT 15(A) OR STT 15(B))	**P**	**2**	**50**	**--**	**50**	**50**
STS 03	Soft Skill	Seminar	**L/T/P**	**1**	**25**	**--**	**25**	**25**
		Total						**625**

SEMESTER-IV								
Sr. No.	**Course**	**Course Title**	**Theory/ Practical Paper**	**No. of Credits**	**Marks@ 25/Credit**	**Internal Component (50%)**	**Semester End Component (50%)**	**Grand Total**
STT 16	Core XV	Asymptotic Inference	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 17	Core XVI	Operations Research-II	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 18	Core XVII	Multivariate Analysis	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 19	Core XVIII	Reliability and Survival Analysis	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 20 (A)/(B)	Elective Group II	Data Mining Techniques/ Directional Data Analysis/Actuarial Statistics	**L/T**	**4**	**100**	**50**	**50**	**100**
STM 02	Core Project	Project	**P**	**2**	**100**	**--**	**100**	**100**
STS 04	Soft Skill	Seminar	**L/T/P**	**1**	**25**	**--**	**25**	**25**
		Total						**625**

List of Core/ Elective Subjects to be offered

Core Subjects

1. Real Analysis
2. Linear Algebra
3. Distribution Theory
4. Sampling Methods
5. Statistical Computing (R Programming)
6. Practical-I (based on STT 02 and STT 05)
7. Practical-II (based on STT 03 and STT 04)
8. Soft Skill-I
9. Probability Theory
10. Regression Analysis
11. Parametric Inference
12. Calculus
13. Stochastic Processes
14. Practical-III (based on STT 08 and STT 09)
15. Practical-IV(based on STT 07 and STT 10)
16. Soft Skill-II
17. Industrial Statistics
18. Operations Research-I
19. Design of Experiments
20. Testing of hypotheses
21. Practical-V (based on STT 11, STT 12 and STT 14)
22. Practical-VI (based on STT 13 and Elective STT 15(A) OR STT 15(B))
23. Seminar
24. Asymptotic Inference
25. Operations Research-II
26. Multivariate Analysis
27. Reliability and Survival Analysis
28. Project (carrying 100 marks)
29. Seminar

Elective Subjects

Elective Group I (Any one for Third Semester)

1. Time Series Analysis
2. Decision Theory
3. Statistical Methods in Finance

Elective Group II (Any one for Fourth Semester)

1. Data Mining Techniques
2. Directional Data Analysis
3. Actuarial Statistics

NOTE:

- Each semester will have five Theory papers and each theory paper will be of 100 Marks [50 External Exam+ 50 Internal Exam (02 tests each of 15 Marks+20 Marks for Class performance].
- Each Soft Skill and Seminar course will be of 25 marks [External Exam].
- All the Practical, Soft Skill and Seminar courses are compulsory to all the students.
- Each semester is of 625 marks.

- Total marks for I sem+ II sem+ III sem + IV sem = 2500.
- Total degree is of 2500 Marks, converted in the form of 100 credits CBCS system.
- One credit is of 25 marks.
- Minimum 40% Marks are required for passing in each of the above head i.e. separate passing in External Exam and that in Internal Exam.
- Project/ Practical will be evaluated by one external examiner and one internal examiner.
- Project work will commence from 3rd semester. (i)Project carrying 100 marks which is to be given at the beginning of Semester-III and evaluated at the end of Semester-IV.
- Project batch is of minimum 02 and maximum 04 students.
- In paper STT-05 i.e. in Statistical Computing EDA using R software will be taken.
- In STT-12 and STT-17 papers i.e. Operations Research I & II TORA software and Solver tool pack will be used for practical purpose.

Structure of the course: M.A./ M.Sc. (Statistics)-First Semester (CBCS Pattern)

SEMESTER-I								
Sr. No.	**Course**	**Course Title**	**Theory/ Practical Paper**	**No. of Credits**	**Marks@ 25/Credit**	**Internal Component (50%)**	**Semester End Component (50%)**	**Grand Total**
STT 01	Core I	Real Analysis	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 02	Core II	Linear Algebra	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 03	Core III	Distribution Theory	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 04	Core IV	Sampling Methods	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 05	Core V	Statistical Computing (R Programming)	**L/T**	**4**	**100**	**50**	**50**	**100**
STP 01	Core Practical I	Practical-I (based on STT 02 and STT 05)	**P**	**2**	**50**	**--**	**50**	**50**
STP 02	Core Practical II	Practical-II (based on STT 03 and STT 04)	**P**	**2**	**50**	**--**	**50**	**50**
STS 01	Soft Skills	Soft Skill-I	**L/T/P**	**1**	**25**	**--**	**25**	**25**
		Total						**625**

STT 01 REAL ANALYSIS

(Maximum no. of periods = 60)

Unit I: Countability, supremum and infimum of sets of real numbers. Archimedean property, denseness property of rationals. Metric spaces, limit points and interior points of a set, open sets, closed sets etc. **(12L + 3T)**

Unit II: Compactness, Bolzano-Weierstrass theorem, Heine-Borel Theorem. Sequences of real numbers, Cauchy sequence, limit superior, limit inferior, limit and convergence of a sequence of real numbers. Cauchy criterion for convergence. Completeness of R. **(12L + 3T)**

Unit III: Series of real numbers, convergence of series, tests for convergence of series, absolute convergence, Cauchy product of two series and its convergence. Power series and radius of convergence, examples and problems on these concepts. **(12L + 3T)**

Unit IV: Continuous functions, uniform continuity, uniform convergence of sequences and series of functions, term by term differentiation and integration, applications to power series. **(12L + 3T)**

REFERENCES:

1) Apostol T.M.(1985) Mathematical Analysis, Narosa,Indian Ed.
2) Courant R. And John F.(1965) Introduction to Calculas and Analysis, Wiley.
3) Miller K.S.(1957)Advanced Real Calculas,Harper, New York.
4) Rudin ,Walter(1976) Principles of Mathematical Analysis,McGraw Hill.
5) Malik S.C.(2005)Principles of Real Analysis, New Age International (p)Ltd.
6) Bartle R.G.(1976)Elements of Real Analysis, Wiley.

STT 02 LINEAR ALGEBRA

(Maximum no. of periods = 60)

UNIT I: Vector spaces: Vector spaces, subspaces, span of a set, linear dependence, independence, Dimension and Basis. Linear Transformation: Range and kernel of a linear map, Rank and Nullity, Inverse of linear transformation, Rank Nullity theorem, the space L (U, V). **(12L+3T)**

UNIT II: Matrices and Determinants **:**Linear map associated to matrix , matrix associated with linear map, Matrix multiplication, Rank and Nullity of matrix, Transpose of matrix, Elementary row operations, System of linear equations, Matrix inversion, Properties of determinants, Eigen values and Eigen vectors, algebraic multiplicity and geometric multiplicity, Cayley Hamilton theorem, Minimal polynomial. **(12L+3T)**

UNIT III: Inner product spaces and Quadratic forms: Inner product spaces, orthogonality, orthonormal basis, Gram Schmidt orthogonalization process, Classification of quadratic forms, rank and signature. **(12L+3T)**

UNIT IV: Canonical forms and generalized inverse: Echelon form, normal form, Hermite canonical form, Diagonalisation, Singular value decomposition, Jordan canonical form, Kroneker product, generalized inverse. **(12L+3T)**

Text Books:

For units I to II (3.1 to 3.6, 4.1 to 4.6, 5.1 to 5.9, 6.1 to 6.9)

1) Krishnamurthy, Mainra and Arora, An introduction to Linear Algebra, East- west press pvt. Ltd. New Delhi.

For units III and IV (4.4 to 4.6, 8.6 to 8.8, 7.1 to 7.6, 9.1 to 9.3)

2) Ramchandra Rao and Bhimasankaram, Linear Algebra, 2nd edition, Hindustan book agency (India).

REFERENCES:

1) T. M. Karade and J. N. Salunke, Introductory Linear Algebra, Ist Edition 2012, Sonu Nilu Publication.
2) S. K. Mapa, Higher algebra Abstract and Linear, 10th edition, SARAT Book distributors, Calcutta.
3) Hoffman and Kunze, Linear Algebra, Prentice Hall India.
4) Friedberg , Insel, Spence, Linera Algebra, 4th edition, Prentice Hall India.

STT 03 DISTRIBUTION THEORY

(Maximum no. of periods = 60)

UNIT I: Brief review of basic distribution theory: Random experiment and its sample space, events, Probability axioms, Random variables, Discrete random variables, Continuous random variables, P.d.f., P.m.f. ,c.d.f. of random variables, M.g.f., p.g.f. c.g.f., characteristic function of random variables, Moments: raw moments, Central moments, Factorial moments. **(12L+3T)**

UNIT II: Standard discrete and continuous distributions: Bernoulli, Binomial, Geometric, Negative Binomial, Poisson, Hypergeometric distributions. Exponential, Normal, Gamma ,Beta, Uniform, Chi-square, Lognormal, Weibull, Cauchy distributions. M.g.f., p.g.f., c.g.f., characteristic function , Moments of above distributions. Properties of above distributions. **(12L+3T)**

UNIT III: Joint ,Marginal and Conditional distributions, Independence of random variables. Bivariate normal distributions. Joint p.d.f., Marginal p.d.f.s, Conditional p.d.f. , joint m.g.f., Some properties. Multinomial distribution: joint p.m.f., Marginal p.m.f., Conditional p.m.f., Joint m.g.f. Functions of random variables and their distributions, Compound, Truncated and Mixture Distributions.

(12L+3T)

UNIT IV: Sampling Distributions: Introduction, Sampling distribution of statistics from univariate normal random samples. Non-central Chi-square, t and F-distributions and their properties. Quadratic forms under Normality, Fisher Cochran's theorem. Order Statistics **(12L+3T)**

REFERENCES:

1)Rohatgi V.K. and Ehsanes Saleh A.K.MD.(2003) An Introduction to probability theory and Mathematical Statistics (Wiley Eastern ,2nd Ed.)
2)Hogg R.V. and Craig A.T.(1978) Introduction to Mathematical Statistics(5th Ed. Pearsons Education)
3)Hogg R.V. and Tanis E.(2002)An Probability and Statistical Inference(6th Ed.Pearsons Education)
4)Rao C.R.(2002)Linear Statistical Inference and its Applications(2nd Ed.,Wiley Eastern)
5)Dudewicz E.J.and Mishra S.N.(1988)Modern Mathematical Statistics,(Wiley & Sons)

Additional Refernces:

1. Pitman J.(1993) Probability,(Narosa Publishing House)
2. Johnson S.and Kotz (1972)Distributions in Statistics(Vol.I,IIand III,Houghton and Miffin)
3. Cramer H.(1946)Mathematical Methods of Statistics(Princeton)

STT 04 SAMPLING METHODS

(Maximum no. of periods = 60)

UNIT I: Concept of population and sample, need for sampling, Census and sample surveys, basic concepts in sampling and designing of large-scale survey design, sampling scheme and sampling strategy. Sampling and Non-sampling errors, Response and non-response errors. Basic methods of sample selection: SRSWR, SRSWOR. **(12L+3T)**

UNIT II: Stratified sampling: Formation of strata and number of strata, Allocation problems and estimation problems, cost and variance analysis. Systematic sampling and related results on estimation of population total, mean and proportion. **(12L+3T)**

UNIT III: Use of supplementary information for estimation: Ratio and Regression estimators and their properties and MSEs. Unbiased and almost Unbiased ratio type estimators. **(12L+3T)**

UNIT IV: Unequal Probability Sampling Designs: Inclusion probabilities, Horwitz - Thompson estimator and its properties. PPSWR, PPSWOR methods (including Lahiri's scheme) and related estimators of a finite population mean (Heansen-Horwitz and Desraj estimators for a general sample size and Murthy's estimator for a sample of size, Midzuno sampling design). Cluster sampling, Estimator of population mean and its properties. Two-stage sampling. Double sampling and its uses in ratio and regression estimation. **(12L+3T)**

REFERENCES:

1) Chaudhari A. And Mukerjee R. (1988) Randomized Response: Theory and Techniques, New York, Marcel Dekker Inc.
2) Cochran W.G.(1984) Sampling Techniques, Wiley.
3) Des Raj and Chandok(1999)Sample Survey Theory, Narosa.
4) Murthy M. N.(1977) Sampling Theory and Methods, Statistical Pub.Society, Calcutta.
5) Sukhatme P.V., Sukhatme B.V. and Ashok C.(1984)Sampling Theory of Surveys with Applications, Iowa state University Press and IARS.
6) Singh D. and Chaudhary F. S. (1986) Theory and Analysis of Sample Survey Designs, New Age International Publishers.
7) Mukhopadhay P.(2002) Theory and Methods of Sample Survey, Chpman and Hall.

STT 05 STATISTICAL COMPUTING

(Maximum no of periods: 60)

UNIT I: Introduction: History of R programming, starting and ending R, R commands, Data types, Getting help in R, R use as calculator. Descriptive Statistics: Diagrammatic representation of data, measures of central tendency, measures of dispersion, measures of skewness and kurtosis. **(12L+3T)**

UNIT II: Probability and probability distributions: problems on finding basic probabilities, some special discrete distributions and continuous probability distributions, probabilities and inverse for various distributions, sketching graphs for various distributions. **(12L+3T)**

UNIT III: Statistical inference: Sampling distribution of sample means, estimation of parameters, hypothesis testing, goodness of fit tests. **(12L+3T)**

UNIT IV: Correlation, inference procedure for correlation coefficient, bivariate correlation, multiple correlations. Linear regression and its inference procedure. Simple optimization method, direct search, grid search, interpolatory search, gradient search. Newton-Raphson method, Muller's method, Aitken's extrapolation. **(12L+3T)**

REFRENCES

1) Normal Maltoff (2009) The art of R programming.
2) Purohit S. G., Gore S. D. and Deshmukh S. K. (2010) Statistics using R, Narosa.
3) W. John Braun, John Braun, Duncan James Murdoch(2007) First Course in Statistical Programming with R, Cambridge University Press.
4) M. D. Ugarte, A. F. Militino, A. T. Arnholt (2008) Probability and Statistics with R, CRC Press.
5) Peter Dalgaard (2008) Introductory Statistics with R, Springer.
6) Michael J. Crawley (2007) The R Book, John Wiley and Sons.

Structure of the course: M.A./M.Sc. (Statistics)-Second Semester (CBCS Pattern)

SEMESTER-II								
Sr. No.	**Course**	**Course Title**	**Theory/ Practical Paper**	**No. of Credits**	**Marks@ 25/Credit**	**Internal Component (50%)**	**Semester End Component (50%)**	**Grand Total**
STT 06	Core VI	Probability Theory	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 07	Core VII	Regression Analysis	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 08	Core VIII	Parametric Inference	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 09	Core IX	Advanced Calculus	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 10	Core X	Stochastic Processes	**L/T**	**4**	**100**	**50**	**50**	**100**
STP 03	Core Practical III	Practical-III(based on STT 08 and STT 09)	**P**	**2**	**50**	**--**	**50**	**50**
STP 04	Core Practical IV	Practical-IV(based on STT 07 and STT 10)	**P**	**2**	**50**	**--**	**50**	**50**
STS 02	Soft Skill	Soft Skill- II	**L/T/P**	**1**	**25**	**--**	**25**	**25**
		Total						**625**

STT 06 PROBABILITY THEORY

(Maximum no of periods: 60)

Unit I: Axiomatic definition of Probability, Probability measure on a s-field, Probability space (definition only), Properties of probability measure. Independence of two events and n>2 events, mutual independence,Sequence of independent events, Independent classes of events, Borel- Cantelli Lemma, Random Variable, Expectation of random variable, Linear properties of expectation.

(12L+3T)

Unit II: Distribution functions and its properties, convergence of sequence of random variables, convergence almost sure, convergence in probability, convergence in distribution, convergence in r^{th} mean, inter relations between different types of convergences. Characteristic function, properties, inequalities, uniqueness theorem, Inversion theorem, continuity theorem. **(12L+3T)**

Unit III: Weak law of large numbers, Strong law of large numbers, Chebyshev's weak law of large numbers, Khinchin‟s weak law of large numbers, Kolmogorov's strong law of large numbers (statement only), Kolmogorov's inequality. **(12L+3T)**

Unit IV: Central Limit Theorem, Demoivre's, Laplace, Lindeberg -Levy, Lindeberg - Feller (sufficiency only) and applications. Multivariate central limit theorem. **(12L+3T)**

REFERENCES:

1) Bhat B. R. (2000) Modern Probability Theory, New age international.
2) Ash Robert (1972) Real analysis and probability, Academic press.
3) Mukhopadhy P. (2002) Theory of Probability, New central book agency, Calcutta.
4) Vardhan S. R. S. (2000) Probability Theory, New York University.
5) Billingsley P. P. (1986) probability and measure, Wiley.
6) Dudewicz E. J. and Mishra S. N. (1988) Modern Mathematical statistics, Wiley Int. student‟s Edition.
7) RohatgiV. K. (1984) An introduction to probability theory and Mathematical Statistics, Wiley Eastern.

STT 07 REGRESSION ANALYSIS

(Maximum no. of periods: 60)

UNIT I: Simple linear regression, assumptions, least square (LS) estimators of parameters, standard error of estimators, testing of hypothesis for coefficient of regression, s.e. of prediction, testing of hypotheses about parallelism (Slopes) ,equality of intercepts, congruence, extrapolation, optimal choice of independent variables, , diagnostic checks and correction: graphical technique, tests for normality, uncorrelatedness, homoscadasticity, lack of fit, detection of outliers, Remedies. Weighted LS. **(12L+3T)**

UNIT II: Multiple regression: Standard Gauss-Markov setup, least square estimation, error and estimation spaces, variance and covariance of LS estimators, properties of LS estimators, testing of hypothesis for one and more than one linear parametric functions, confidence intervals Multicollinearity: Consequences, detection and remedies, autocorrelation consequences, Durbin Watson test, estimation of parameters in autocorrelation. **(12L+3T)**

UNIT III: Multiple correlations, partial correlation coefficient. Test for significance of simple, multiple and partial correlation coefficients, variable selection procedures. Residual and residual diagnostics, transformation of variables: Box- Cox power Transformation, generalized weighted least sequence. Mallows Cp Statistics, forward and backward selection method. **(12L+3T)**

UNIT IV: Logistic regression: Logit transform, ML estimation, tests of hypothesis, Wald test, LR test, score test, test for overall regression Ridge regression, robust regression. Non-linear regression models, Least squares estimation in nonlinear regression, model building and diagnostics. **(12L+3T)**

REFERENCES:

1) Joshi D.D. (1987) Linear Estimation and design and analysis of experiments, Wiley Eastern.
2) Giri N (1986) Analysis of variance, South Asia Publishers.
3) Cook R.D. And Weisberg S. (1982) Residual and influence in Regression, Chapman and Hall.
4) Draper N.R.and Smity, H (1998) applied Regression analysis, 3rd ed. Wiley.
5) Rao. C.R. (2002) Linear Statistical Inference and its Applications, 2nd Ed. Wiley.
6) Weisberg S. (1985) Applied Linear Regression, Wiley.
7) Montegomery D.C., Peck, E.A. and Vining G.G.(2003). Introduction to Linear Regression Analysis,3rd Ed. Wiley.
8) Ratkowsky, D. A.(1983) Nonlinear regression modeling, Marcel Dekker.
9) Kutner, Neter, Nachtsheim and Wasserman (2003) Applied Linear Regression, 4th Ed., McGraw-Hill.

STT 08 PARAMETRIC INFERENCE

(Maximum no of periods: 60)

UNIT I: Introduction of Parametric models, Point estimation, Interval estimation, Joint distribution of a sample and sampling distribution of a Statistic. Likelihood function; examples from standard discrete and continuous models . **(12L+3T)**

UNIT II: Information in data about the parameters and variation in likelihood function, concept of no information. Sufficiency, Fisher's concept of sufficiency, Sufficient Statistic, Neyman Factorizability criterion, Likelihood equivalence, Minimal sufficient Statistic. **(12L+3T)**

UNIT III: Invariance property of sufficiency under one-one transformation of sample space. Exponential families and Pitman families. Fisher information for one and several parameters models.Maximum Likelihood methods, Methods of moments and percentiles. UMVUE, Rao-Blackwell theorem and its applications. Completeness property of family of distributions. Lehmann-Scheffe theorem, Necessary and sufficient condition for UMVUE. Cramer-Rao lower bound approach. **(12L+3T)**

UNIT IV: introduction to Bayesian estimation, prior & posterior distribution, loss function, principle of minimum expected posterior loss, quadratic & other common loss functions, conjugate family of prior distribution & its examples. **(12L+3T)**

REFERENCES:

1) Kale B.K. (1999) A First course on Parametric Inference, Narosa.
2) Casella G. & Beregar R.L.(2002) Statistical Inference, 2nd edition, Duxbury Advanced series.
3) Ferguson T.S (1996): A course on large sample Theory, Chapman and Hall.
4) Dudewitz E.J. & Mishra S.N.(1988) Modern mathematical Statistics, JohnWiley.
5) Lehman E.L. (1988) Theory of point estimation, John Wiley.
6) Lehman E.L. (1986) Testing of statistical hypotheses, John Wiley.
7) Rohatgi V.K and Saleh A.K. Md. E (2001) Introduction to Probability Theory and Mathematical Statistics, John –Wiley and Sons.
8) Rao C. R.(1973) Linear Statistical Inference & its Applications, 2nd Ed., Wiley.
9) George Casella, Roger L. Berger (2001) Statistical Inference,2nd Ed., Duxbury press.
10) Zacks S. (1971) Theory of Statistical Inference John Wiley and Sons, New York.

STT 09 CALCULUS

(Maximum no. of periods: 60)

Unit I: Review of calculus of one variable: differentiability, mean value theorem and Taylor series expansion. Functions of several variables: Continuity, directional derivatives, differentials of functions of several variables, the gradient vector. **(12L+3T)**

Unit II

Differentials of composite functions and the chain rule, the mean value theorem, a sufficient condition for the existence of the differential, partial derivatives of higher order and Taylor's formula. Applications of partial differentiation, Jacobians. **(12L+3T)**

Unit III

Inverse function theorem (without proof), implicit function theorem (without proof), extremum problems. Riemann and Riemann–Stieltjes integrals, integration by parts, mean value theorem. **(12L+3T)**

Unit IV

Improper Riemann – Stieltjes integrals: Improper integrals of first and second kind for one variable. Uniform convergence of improper integrals, differentiation under the sign of integral – Leibnitz rule. Multiple Integrals and evaluation of multiple integrals by repeated integration. Mean value theorem for multiple integrals. **(12L+3T)**

REFERENCES:

1. Apostol T.M. (1975). Mathematical Analysis: A modern approach to advanced calculus. (Addison-Wesley)
2. Bartle, R. G. (1976). Elements of Real Analysis. (John Wiley)
3. Kreyszig, E. (1975). Advanced Engineering Mathematics (Wiley Eastern)
4. Rudin, W. (1985). Principles of Mathematical Analysis (McGraw-Hill)

STT 10 STOCHASTIC PROCESSES

(Maximum no. of periods = 60)

Unit I: Introduction to stochastic Processes (SP's) Classification of SP's according to State space & time domain. Markov chain, countable state Markov chain, calculation of n-step transition probability & its limit. Chapman-Kolmogorov equation, Stationary distribution, classification of states, criteria for various states, Ergodic theorem. **(12L+3T)**

Unit II: Random walk & gambler's ruin problem, absorbing and reflecting barriers, probability of eventual absorption, expected duration of game, random walk in 2 & 3 dimension. First passage time distribution. **(12L+3T)**

Unit III: Discrete state space & continuous time Markov chain, Poisson process, properties of Poisson process, pure birth, pure death, Birth and death process. **(12L+3T)**

Unit IV: Continuous state space, continuous time Markov chain, Wiener process, Wiener process as a limit of random walk, differential equation of Wiener process, first passage problem in Wiener process. Renewal and delayed renewal processes, related theorems, key renewal theorem (without proof) and its application. Galton-Watson Binaymi Branching process. Probability of ultimate extinction. Stationary Process: Weak Stationary and strong stationary processes. **(12L+3T)**

REFERENCES:

(1) Medhi, J. (1994) Stochastic Processes, Wiley Eastern.
(2) Bhat, B. R. (2000) Stochastic Models: Analysis and Applications, New Age International, India.
(3) Adke, S. R. and Manjunath, S.M. (1984) An Introduction to finite Markov Processes, Wiley Eastern.
(4) Parzen E. (1962) Stochastic Process, Holden-Pay.
(5) Karlin & Taylor, A. (1975) First Course in Stochastic Process, (Vol.1) Academic Press.
(6) Cinlar E.(1975) Introduction to Stochastic Process, Prentice Hall.
(7) Srinivas and Mehta (1976) Stochastic Processes, Tata McGraw Hill, New Delhi.
(8) Feller, W.(1968) Introduction to Probability and its Applications, (Vol.1) Wiley Eastern.
(9) Harris, T.E. (1963). The Theory of Branching Processes, (Springer-Verlag).
(10) Hoel, P.G., Port, S. C. and Stone, C. J. (1972) Introduction to Stochastic Processes, Houghton Miffin & Co.
(11) Jagers, P. (1974) Branching Processes with Biological Applications, Wiley.
(12) Ross, S. (2005) Introduction to Probability Models, 6th Ed. Academic Press.
(13) Taylor and Karlin (1984) An Introduction to Stochastic Modeling, Aca. Press

Structure of the course: M.A. /M.Sc. (Statistics)-Third Semester (CBCS Pattern)

SEMESTER-III								
Sr. No.	**Course**	**Course Title**	**Theory/ Practical Paper**	**No. of Credits**	**Marks@ 25/Credit**	**Internal Component (50%)**	**Semester End Component (50%)**	**Grand Total**
STT 11	Core XI	Industrial Statistics	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 12	Core XII	Operations Research-I	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 13	Core XIII	Design of Experiments	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 14	Core XIV	Testing of hypotheses	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 15 (A)/(B)/ (C)	Elective Group I	Time Series Analysis/ Decision Theory/Statistical Methods in Finance	**L/T**	**4**	**100**	**50**	**50**	**100**
STP 05	Core Practical III	Practical-V (based on STT 11, STT 12 and STT 14)	**P**	**2**	**50**	**--**	**50**	**50**
STP 06	Core Practical IV	Practical-VI (based on STT 13 and Elective) STT 15(A) OR STT 15(B))	**P**	**2**	**50**	**--**	**50**	**50**
STS 03	Soft Skill	Seminar	**L/T/P**	**1**	**25**	**--**	**25**	**25**
		Total						**625**

STT 11 INDUSTRIAL STATISTICS

(Maximum no. of periods = 60)

Unit I: Basic concepts of process monitoring and control. Review of control charts for attributes and variable data. O. C. and ARL of control charts. Cusum & V-masks charts. **(12L+3T)**

Unit II: Concepts of AQL, LTPD, AOQL average amount of inspection and ASN functions. Acceptance sampling plans for attributes inspection, single, double and sequential sampling plans and their properties. Continuous sampling plans of Dodge type and their properties. **(12L+3T)**

Unit III: Capability indices Cp, Cp_k and Cp_m, estimation, confidence intervals and tests of hypothesis relating to capability indices for normally distributed characteristics. **(12L+3T)**

Unit IV: The weighted control charts: Exponential Weighted Moving Average chart. Multivariate SPC: Multivariate quality control problem, description of Multivariate data, The Hotelling T^2 control chart, Multivariate EWMA control chart, regression adjustment, Latent structure methods. Quality Systems: ISO 9000 standards, QS 9000 standards, concept of six sigma. Total Quality management. Taguchi Design.

(12L+3T)

REFERENCES:

(1) Montgomery D.C. (1996) Introduction to Statistical Quality Control, Wiley.
(2) Wetherill G.B. (1977) Sampling Inspection & Quality Control, Halsted Press.
(3) Logothetis N. (1992) Managing Total Quality, Prentice Hall of India.
(4) Oakland J.S. (1989) Total Quality Management; Butterworth- Heinemann.
(5) Mittog H.J. and Rinne H. (1993) Statistical Methods of Quality Assurance.
(6) Guenther W.C (1981) Sampling Inspection in Statistical Quality Control Charter Grifits.
(7) Kotz S. (1993) Process capability indices, Chapman and Hall.
(8) Abraham Bovas (1998) Quality Improvement through statistical methods
(9) Birkhauser.
(10) Barlow R.E. And Proschan F. (1985) Statistical Theory of methods reliability and Life Testing ,Holt Rinehart and Winston.
(11) Lawless J.F. (1982) Statistical Models and methods of life Time Data, John Wiley.
(12) Bain L.J. And Engelhard (1991) Statistical Analysis of Reliability and Life Testing models Marcel Dekker.
(13) Nelson W. (1982) Applied Life Data Analysis, John Wiley.
(14) Zacks S. (1992) Introduction to reliability analysis Probability Models and statistical Methods, Springer-verlag.
(15) Mahajan M. (2004) Statistical Quality Control.

STT 12 OPERATIONS RESEARCH-I

(Maximum Number of Periods: 60)

UNIT I: Operations research & its scope, Necessity of operations research in industry, Introductions to Linear programming problems, General linear programming problems, Mathematical Formulation of L.P.P., Basic solution, Important theorems, solution of linear programming problem, Graphical method for solution, convex set , some important theorems, Revised simplex method, dual simplex method. **(12L+3T)**

UNIT II: Theory of Simplex methods: Introduction, slack and surplus variables, some definitions and notations, Fundamental theorems of linear programming, BSF from F.S., Improved B.S.F. Unbounded solution, optimality of solutions. **(12L+3T)**

UNIT III: computational procedure of simplex method for the solution of a maximization L.P.P., artificial variable technique, duality and sensitivity analysis. **(12L+3T)**

UNIT IV: Introduction, competitive game, finite and infinite game, two person zero sum game, rectangular game , solution of game, saddle point, solution of a rectangular game with saddle point. PERT-CPM, product planning control with PERT-CPM. **(12L+3T)**

REFERENCES:

1) R. K. Gupta "Linear Programming",Krishna Prakashan Mandir.
2) F.S.Hillier and G.J.Liebermann,(1995) Introduction to Operations Research (6^{th} Ed.) Mc Graw Hill.
3) Kantiswaroop, P.K.Gupta and Manmohan, Operations Research, Sultan Chand & Sons, New Delhi.
4) G.Hadley, Linear Programming, Narosa publishing House, 1995.
5) G.Hadley, Nonlinear and Dynamic Programming, Addison-Wesley, Reading Mass.
6) H.A.Taha, Operations Research – An Introduction, Macmillan Publishing Company, Inc, New York.
7) S.S.Rao, Optimization Theory and Applications, Wiley Eastern Ltd., New Delhi.
8) P. K. Gupta and D. S. Hira, Operations Research – A Introduction. S. Chand & company Ltd, New Delhi.
9) N. S. Kambo, Mathematical Programming Techniques. Affiliated East-West Press Pvt. Ltd, New Delhi.

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STT 13 DESIGN OF EXPERIMENTS

(Maximum no. of periods = 60)

UNIT I: General Linear Model: Definition, assumption, concept of estimability, Least square estimation, Best Linear Unbiased Estimator (BLUE). Error space, Gauss-Markov theorem, Estimation of error Variances. **(12L+3T)**

UNIT II: Basic designs–CRD, RBD, LSD and their analyses, Missing plot techniques in RBD and LSD. Tests for comparing pairs of treatment means: Tukey's test, Fishers LSD test, Duncan's Multiple Range Test (DMRT), Newman- Keul's test, Dunnet test. ANCOVA: One way and Two way classification. Definition and analysis of split plot design, split-split plot design and Strip plot design. **(12L+3T)**

Unit III: General factorial experiments, factorial effects, study of 2^2, 2^3 , 2^4 and 2^k factorial experiments. Study of 3^2, 3^3 designs : Contrasts for linear and quadratic effects, statistical analysis of 3^k design. **(12L+3T)**

Unit IV: Fractional factorial experiments. Resolution III, IV and V of a design aberration of a design. Confounding in factorial experiments, complete and partial confounding, concept of generalized interaction. Elementary parametric relations and analysis of BIBD. Definitions and parametric relations of PBIBD. Definition and analysis of Quasi-Latin square designs, Youden square design. Cross-over designs. **(12L+3T)**

REFERENCES:

(1) Alok Dey (1986) Theory of Block Designs, Wiley Eastern.
(2) Das, M.N. and Giri, N. (1979) Design and Analysis of Experiments, Wiley.
(3) Joshi, D. D. (1987) Linear Estimation and Design of Experiments, John Wiley.
(4) Montgomery, D.C. (2005) Design & Analysis of Experiments, Wiley.
(5)Chakrabarti M. C. (1962) Mathematics of Design and Analysis of Experiments, Asia
Pub. Hs.
(6) Cochran W.G. & Cox D.R.(1957) Experimental Designs, 2nd Ed., JohnWiley.
(7) Dean A. M. & Voss D. (1999) Design and Analysis of Experiments, Springer.
(8) Dey A. & Mukerjee R. (1999) Fractional Factorial Plans, John Wiley.
(9) Dey A. (1986) Theory of Block Designs, Wiley Eastern.
(10)John J.A. & Quenouille M.H. (1977) Experiments: Design and Analysis, Charles & Griffin.
(11) Kempthorne, O. (1976) Design and Analysis of Experiments, John Wiley.
(12) Khuri A.I. & Cornell J.A. (1996) Response Surface Designs and Analysis. 2nd Ed.,Marcel Dekker.
(13) Raghavarao D. (1971) Construction and Combinatorial Problems in Design of Experiments, John Wiley.

STT 14 TESTING OF HYPOTHESES

(Maximum no of periods: 60)

UNIT I: Problem of testing of hypothesis: Simple and Composite hypotheses. Randomized and non-randomized tests. Most powerful test, Neyman-Pearson Lemma and its applications. Determination of minimum sample size to achieve the desired strengths. **(12L+3T)**

UNIT II:Composite hypotheses: Monotone likelihood ratio (MLR) property, power function of a test, existence of UMP tests for one-sided alternatives. UMP tests for two sided alternatives, their existence and non-existence. Examples. **(12L+3T)**

UNIT III: Generalized Neyman Pearson Lemma: Unbiased test, UMPU tests and their existence in the case of exponential families. (statements of the theorems only), Similar tests, test with Neyman structure. **(12L+3T)**

UNIT IV: Problem of confidence intervals, relation with testing of hypotheses problem, UMA and UMAU confidence intervals, shortest length confidence intervals. Likelihood ratio test, Application to standard distributions. Goodness of fit test based on Chi-square distribution, application to contingency tables. **(12L+3T)**

Reference Books:

1. Kale B.K. (1999): A first Course on Parametric Inference-Narosa
2. Rohatgi V.K.(1988): Introduction to Probability and Mathematical Statistics, Wiley Eastern Ltd. New Delhi. Student Edition.
3. Dudewicz E.J. & Mishra S.N.(1988): Modern Mathematical Statistics, Wiley Series
4. Lehman E.L. (1987): Theory of Testing of Hypotheses. Student Edition.
5. Ferguson T.S. (1967): Mathematical Statistics*:* A decision Theoretical Approach. Academic Press.
6. Zacks S.(1971): Theory of Statistics Inference- John Wiley and Sons, New York.

STT 15 TIME SERIES ANALYSIS/
DECISION THEORY/
STATISTICAL METHODS IN FINANCE

(A) TIME SERIES ANALYSIS

(Maximum no. of periods = 60)

UNIT I: Time-series as discrete parameter stochastic process. Auto covariance and autocorrelation functions and their properties. **(12L+3T)**

UNIT II: Exploratory Time Series Analysis: Tests for trend and seasonally, Exponential and Moving average smoothing. Holt winters smoothing. Forecasting based on smoothing, adaptive smoothing. **(12L+3T)**

UNIT III: Stationary processes: (i) moving average (MA), (ii) Auto Regressive(AR), (iii) ARMA and (iv) AR integrated MA (ARIMA) models, Box-Jenkins models. Discussion, (without proof) of estimation of mean, auto covariance and auto correlation functions under large sample theory. **(12L+3T)**

UNIT IV: Choice of AR and MA periods, Estimation of ARIMA models parameters. Forecasting, Residual analysis and diagnostic checking.Spectral analysis of weakly stationary process, Periodogram and Correlogram analysis. Spectral Decomposition of weakly AR process and representations as one sided MA process- necessary and sufficient conditions. **(12L+3T)**

REFERENCES:

1) Anderson, T. W (1971) The Statistical Analysis of Time Series, Wiley, N.Y.
2) Box, G.E.P. and Jenkins, G.M. (1976) Time Series Analysis-Forecasting and Control, Hodlen-day, San Francisco.
3) Kendall, Sir Maurice and Ord. J. K. (1990) Time Series, 3rd Ed., Edward Arnold.
4) Montgomery, D. C. and Johnson, L. A. (1977) Forecasting and Time SeriesAnalysis, McGraw Hill.
5) Brockwell P.J. and Davis R.A. (1991) Time Series: Theory and Methods, 2nd Ed., Springer-Verlag.
6) Fuller W.A. (1976) Introduction to Statistical time series, John Wiley N.Y.
7) Priestley M.B. (1981) Spectral analysis and time Series Griffin London.
8) Kendall M.G. And Stuart A. (1996) The advanced theory of Statistics, Vol. 3, Charles Griffin London.
9) Bloomfield P (1976) Fourier analysis of Time series – an introduction, Wiley.
10) Granger C.W. J and Hatanks (1964) Spectral analysis of economic Time Series, Princeton University Press N.J.
11) Koopmens C.R. (1973) The Spectral analysis of time series, Academic presses.
12) Nelson C.R. (1973) Applied Time Series for managerial forecasting, Holden –day.
13) Findley D.F.(1981) Applied Time Series analysis, Academic Press.
14) Wethirll G.B. (1986) Regression analysis with applications, Chapman Hall.

(B) DECISION THEORY

(Maximum no. of periods = 60)

Unit I: Decision problem, loss function, risk function, randomized and non-randomized decision rule. Decision principles (Conditional Bayes, Frequentist). Testing and estimation problem as decision problems. Optimal decision rule.

(12L+3T)

Unit II: Concept of admissibility and completeness, Bayes rules, minimax decision rule. Admissibility of Bayes rules. Existence of Bayes decision rule. **(12L+3T)**

Unit III: Definition of non-parametric test, advantages and disadvantages of nonparametric tests. Single sample problems. (i) Test of randomness (ii) Tests of goodness of fit: Empirical distribution function. Kolmogorov-Smirnov test, comparison of Chi-squareand KS test. (iii) Problem of location: Sign test, Wilcoxon's signed rank test, Wilcoxon paired sample signed rank test. **(12L+3T)**

Unit IV: Two Sample Problems: Different types of alternative, sign test, Wilcoxon two sample rank sum test, Wald-Wolfiwitz run test, Mann-Whitney-Wilcoxon test, median test. K-S two sample test. One sample U statistic, Kernel and symmetric Kernel, variance of U statistic, two sample U statistics, linear rank statistics and their distribution properties under null hypothesis. **(12L+3T)**

REFERENCES:

1) Ferguson T. S. (1967) Mathematical Statistics, Academic Press, New York.
2) Fraser, D.A.J. (1957) Non-parametric methods in Statistics, John Wiley.
3) Gibben J.D.(1992) Non Parametric Statistical inference, Marcel Dekker, Inc., New York.
4) Goon A.M., Gupta M.K., Dasgupta : An Outline of Statistical Inference. The World Press Pvt. Ltd.
5) Berger, J.O. (1980) Statistical Decision Theory: Foundations, Concepts and Methods, Springer-Verlag.
6) Berger, J.O. (1985) Statistical Design Theory and Bayesian Analysis, 2nd ed., Springer-Verlag.
7) Gupta S. S. and Huang, D. (1981) Multiple Statistical Decision Theory, Springer-Verlag, New York.

(C) STATISTICAL METHODS IN FINANCE

(Maximum no of periods: 60)

UNIT I: Introduction and behavior of Returns, Origins of Random Walk Hypothesis, Efficient Market Hypothesis(EMH). Discrete and Continuous compounding. **(12L+3T)**

UNIT II: Trading Off Expected Return and Risk, One Risky Asset and Two Risky Assets. Combing Two Risky Assets with a Risk-Free Asset. Risk-Efficient Portfolios with N Risky Assets. **(12L+3T)**

UNIT III: Introduction to Capital Asset Pricing Model(CAPM). Capital Market Line(CML). Betas and the Security Market Line, Security Characteristic Line. Estimation of Beta and Testing CAPM. **(12L+3T)**

UNIT IV: Introduction of Option Pricing, Call Options. The law of One Price. Time value of Money and Present Value, Pricing Calls. Martingales. Introduction of Fixed Income Securities. Zero-Coupon Bonds, Yield to Maturity, Term Structure. Introduction of Resampling, Resampling and efficient Portfolios. Need for Risk Management, Value-At-Risk(VaR) with one asset, VaR for a Portfolio Assets. **(12L+3T)**

REFERENCES:

1) David Ruppert,(2004) Statistics and Finance –An Introduction, Springer Texts in Statistics.
2) R. A. Johnson and D. W. Wichern,(2007) Applied Multivariate Statistical Analysis, 6th edition, Prentice Hall, New Jersey.

Structure of the course: M.A. / M.Sc. (Statistics)-Fourth Semester (CBCS Pattern)

SEMESTER-IV								
Sr. No.	**Course**	**Course Title**	**Theory/ Practical Paper**	**No. of Credits**	**Marks@ 25/Credit**	**Internal Component (50%)**	**Semester End Component (50%)**	**Grand Total**
STT 16	Core XV	Asymptotic Inference	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 17	Core XVI	Operations Research-II	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 18	Core XVII	Multivariate Analysis	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 19	Core XVIII	Reliability and Survival Analysis	**L/T**	**4**	**100**	**50**	**50**	**100**
STT 20 (A)/(B)/ (C)	Elective Group II	Data Mining Techniques/ Directional Data Analysis/Actuarial Statistics	**L/T**	**4**	**100**	**50**	**50**	**100**
STP 07	Core Practical III	Practical-VII (based on STT 16, STT 17 and STT 20)	**L/T**	**2**	**50**	**--**	**50**	**50**
STP 08	Core Practical IV	Practical-VIII (based on STT 18 , STT 19)	**P**	**2**	**50**	**--**	**50**	**50**
STM 02	Core Project	Project	**P**	**4**	**100**	**--**	**100**	**100**
STS 04	Soft Skill	Seminar	**T/L/P**	**1**	**25**	**--**	**25**	**25**
		Total						**625**

STT 16 ASYMPTOTIC INFERENCE

(Maximum no of periods: 60)

UNIT I: Consistency and asymptotic normality (CAN) of real and vector parameters. Invariance of consistency under continuous transformation.Invariance of CAN estimators under differentiable transformations, generation of CAN estimators using central limit theorem. **(12L+3T)**

UNIT II: Method of moments, method of maximum likelihood, Special cases such as exponential class of densities and multinomial distribution, Cramer-Huzurbazar theorem, method of scoring. **(12L+3T)**

UNIT III: Tests based on MLEs. Likelihood ratio tests, asymptotic distribution of log likelihood ratio, Wald Test, Score Test, locally most powerful tests, Bartlett's test for homogeneity of variances. **(12L+3T)**

UNIT IV: Applications to categorical data analysis, three dimensional contingency tables, Pearson's chi-square test and LR test. Asymptotic comparison of tests. Asymptotic Relative Efficiency (Pitman's), asymptotic normality of posterior distributions. **(12L+3T)**

REFERENCES:

1) Kale B.K. (2005) A First Course on Parametric Inference, Second Edition, Narosa.
2) Cramer, H.(1974) Mathematical Methods in Statistics, Princeton Univ. Press.
3) Rao,C.R.(1995) Linear Statistical Inference and its Applications,Wiley Eastern Ltd.
4) Silvey, S. D.(1975) Statistical Inference, Chapman- Hall.
5) Wilks, S.S.(1962) Mathematical Statistics, John Wiley.
6) Ferguson, T.S. (1996) A Course in Large Sample Theory, Chapman and Hall.

STT 17 OPERATIONS RESEARCH-II

(Maximum no of periods: 60)

UNIT I: Integer Linear Programming Problem (ILPP): The concept of cutting plane, Gomory's method of cutting plane for all ILPP and mixed ILPP, Branch and Bound method. **(12L+3T)**

UNIT II: The Recursive equation approach and characteristic of Dynamic programming, Dynamic programming algorithm, Deterministic processes, Non-sequential discrete optimization-allocation problems. **(12L+3T)**

UNIT III: Inventory models: Inventory problems and their analytical structure.EOQ, deterministic models of inventory control. Inventory (S,s) policy periodic review models with stochastic demand. Probabilistic re-order point, lot size inventory system. **(12L+3T)**

UNIT IV: Basic characteristics of queuing system, different performance measures, steady state solution of Markovian queuing models: M/M/1, M/M/1 with limited waiting space M/M/C, M/M/C with limited waiting space. Imbedded Markov chain method to obtain steady state solution of M/G/1, G/M/1 and M/D/C, Network models. Quadratic programming: Kuhn-Tucker conditions of optimality, methods due to Beale, Wolfe. **(12L+3T)**

REFERENCES:

1) R. K. Gupta "Linear Programming",Krishna Prakashan Mandir.
2) F.S.Hillier and G.J.Liebermann,(1995) Introduction to Operations Research (6th Ed.) Mc Graw Hill.
3) Kantiswaroop, P.K.Gupta and Manmohan, Operations Research, Sultan Chand & Sons, New Delhi.
4) G.Hadley, Linear Programming, Narosa publishing House, 1995.
5) G.Hadley, Nonlinear and Dynamic Programming, Addison-Wesley, Reading Mass.
6) H.A.Taha, Operations Research - An Introduction, Macmillan Publishing Company, Inc, New York.
7) S.S.Rao, Optimization Theory and Applications, Wiley Eastern Ltd., New Delhi.
8) P. K. Gupta and D. S. Hira, Operations Research – A Introduction. S. Chand & company Ltd, New Delhi.
9) N. S. Kambo, Mathematical Programming Techniques. Affiliated East-West Press Pvt. Ltd, New Delhi.

STT 18 MULTIVARIATE ANALYSIS

(Maximum no. of periods: 60)

UNIT I: Multivariate normal distribution, marginal and conditional distribution, singular and nonsingular normal distribution, Characteristic function, Maximum likelihood estimators of the mean vector and covariance matrix. **(12L+3T)**

UNIT II: Wishart Distribution: Wishart matrix- its distribution and properties, Distribution of sample generalized variance. Hotelling's T^2 statistics and its distribution. Application T^2 Statistics and its relationship with Mahalanobis D^2 Statistics. **(12L+3T)**

UNIT III: Principal components, Dimension reduction, Canonical variables and canonical correlation–definition, use, estimation and computation. Multivariate Analysis of Variance (MANOVA) of one and two–way classified data. **(12L+3T)**

UNIT IV: Classification and discrimination procedures for discrimination between two multivariate normal populations–sample discriminant function, probabilities of misclassification and their estimation. **(12L+3T)**

REFERENCES:

1) Anderson T.W. (1983) An Introduction to Multivariate Statistical Analysis, 2nd Ed. Wiley.
2) Giri N.C. (1977) Multivariate Statistical Inference, Academic press.
3) Kshirsagar A.M. (1972) Multivariate Analysis, Marcel Dekker.
4) Morrison D.F. (1976) Mathematical Statistics Methods, 2nd Ed Mc-Graw Hill.
5) Rao.C.R.(2002) Linear Statistical Inference and Its Application 2nd Ed. Wiley.
6) Seber G. A. F. (1984) Multivariate observations Wiley.
7) Sharma S. (1996) Applied multivariate techniques Wiley.
8) Srivastava S. and Khatri C.G. (1979) An introduction to Multivariate Statistics, North Holland.
9) Johnson and Wichern (1992) Applied multivariate Statistical Analysis, Prentice Hall 3rdEd.
10) Roy S.N.(1987) Some Aspects of Multivariate Analysis John Wiley.
11) Muirhead, R.J. (1982). Aspects of Multivariate Statistical Theory, J. Wiley.
12) Bhuyan K.C. (2005) Multivariate Analysis and its application, New Central book age., Ltd. Kolkatta.

STT 19 RELIABILITY AND SURVIVAL ANALYSIS

(Maximum no of periods: 60)

UNIT I: Elements of Reliability, definition and relationship between survival function, hazard function, distribution with DFR and IFR, series and parallel systems. Life testing experiments, stress–strength reliability and its estimation. **(12L+3T)**

.**UNIT II:** Basic concepts of Time, Order and Random Censoring. Life distributions - Exponential Gamma, Weibull, Lognormal, Pareto, Linear Failure rate. Parametric inference Point estimation, Confidence Intervals, Scores, tests based on LR, MLE Life tables, Failure rate, mean residual life and their elementary properties. Ageing classes - IFR, IFRA, NBU, NBUE, HNBUE and their duals, Bathtub Failure rate. **(12L+3T)**

UNIT III: Ageing classes - IFR, IFRA, NBU, NBUE, HNBUE and their duals, Bathtub Failure rate. Estimation of survival function - Actuarial Estimator, Kaplan – Meier Estimator, Estimation under the assumption of IFR/DFR. **(12L+3T)**

UNIT IV: Tests of exponentiality against non-parametric classes - Total time on test, Deshpande test. Two sample problem - Gehan Test, Log rank test. Mantel - Haenszel Test, Tarone -Ware tests. Semi-parametric regression for failure rate-Cox's proportional hazards model with one and several covariates. **(12L+3T)**

REFERENCES:

1) Cox, D.R. and Oakes, D. (1984) Analysis of Survival Data, Chapman and Hall, New York.
2) Gross A.J. and Clark, V. A. (1975) Survival Distributions: Reliability Applications in the Biomedical Sciences, John Wiley and Sons.
3) Elandt - Johnson, R.E. Johnson N.L. (1980) Survival models and Data Analysis, John Wiley.
4) Miller, R.G. (1981) Survival Analysis, Wiley.
5) Zacks, S. Reliability.

STT 20 DATA MINING TECHNIQUES/ DIRECTIONAL DATA ANALYSIS/ ACTUARIAL STATISTICS

(A) DATA MINING TECHNIQUES

(Maximum no of periods: 60)

UNIT I: Basic data mining tasks, Introduction to databases, including simple relational databases, data warehouses and introduction to online analytical data processing. Association rules and prediction, data attributes, applications to electronic commerce. **(12L+3T)**

UNIT II: Unsupervised learning from univariate and multivariate data, Dimension reduction and feature selection. **(12L+3T)**

UNIT III: Supervised learning from moderate to high dimensional input spaces, artificial neural networks and extensions of regression models, regression trees. **(12L+3T)**

UNIT IV: Review of classification methods from multivariate analysis, classification and decision trees. Clustering methods from both statistical and data mining viewpoints, vector quantization. **(12L+3T)**

REFERENCES:

1) Berson, A. and Smith, S.J. (1997) Data Warehousing, Data Mining, and OLAP, McGraw-Hill.
2) Breiman, L., Friedman, J.H., Olshen, R.A. and Stone, C.J. (1984) Classification and Regression Trees, Wadsworth and Brooks/Cole.
3) Han,J. and Kamber.M. (2000) Data Mining; Concepts and Techniques, Morgan Kaufmann.
4) Mitchell, T.M. (1997) Machine Learning, McGraw-Hill.
5) Ripley, B.D. (1996) Pattern Recognition and Neural Networks, Cambridge University Press.

(B) DIRECTIONAL DATA ANALYSIS

(Maximum no of periods: 60)

UNIT I: Graphical representation of data, Frequency distribution, Measures of location, circular variance and concentration, Correction for mean grouping, Measures of skewness and kurtosis. **(12L+3T)**

UNIT II: Circular models, distribution theory, independence, convolution, moments, distributions of an arc, mixtures, lattice distributions, wrapped normal, Cauchy, Poisson distributions, Von Mises, Fisher distribution characteristics functions, Polar distributions, isotropic random walk on the circle. **(12L+3T)**

UNIT III: Point estimation, Cramer Rao type bound, sufficiency, Methods of estimation.Testing hypothesis from parametric models. Neyman-Pearson and likelihood ratio principles. **(12L+3T)**

UNIT IV: Non-parametric methods: Tests for randomness, goodness of fit, Rayleigh's test. Durand and Greenwood's test, Range test, Kuper's test Watson's test, Uniform score tests, Runs test, Rank sum test, Test for dispersion. **(12L+3T)**

REFERENCES:

1) Mardia K.V. (1972): Statistics of Directional data, Academic Press.
2) Batschelet E. (1981): Circular Statistics in Biology, Academic Press.
3) Watson G. S. (1983): Statistics on Spheres, Wiley.

(C) ACTUARIAL STATISTICS

(Maximum no of periods: 60)

UNIT I: Utility theory, insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality. Life table and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables. **(12L+3T)**

UNIT II: Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding. **(12L+3T)**

UNIT III: Life insurance: Insurance payable at the moment's of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance. **(12L+3T)**

UNIT IV: Life annuities: Continuous life annuities, discrete life annuities, life annuities with monthly payments.Net premiums: Continuous and discrete premiums, true monthly payment Premiums and some practical considerations. Net premium reserves: Continuous and discrete net premium reserve, reserves on a semi continuous basis, reserves based on true monthly premiums. **(12L+3T)**

REFERENCES:

1) N. L. Bowers, H. U. Gerber, J. C. Hickman, D. A. Jones and C. J. Nesbitt, Actuarial Mathematics, Society of Actuaries, Itasca, IIIinois, U. S. A. 2nd d.(1997)
2) Deshmukh S.R. (2009) An Introduction to Actuarial Statistics Using R, Uni. Press.
3) Spurgeon E. T. (1972) Life Contingencies, Cambridge University Press.
4) Neill, A. (1977) Life Contingencies, Heinemann.