2-YEAR NEP PG CURRICULUM

M.Sc. STATISTICS PROGRAMME

SUBJECT CODE = STA

FOR POSTGRADUATE COURSES UNDER RANCHI UNIVERSITY, RANCHI

Implemented w.e.f.
Academic Session 2025-26 Onwards

UNIVERSITY DEPARTMENT OF MATHEMATICS
RANCHI UNIVERSITY
Morabadi Campus, Ranchi 834008, Jharkhand. (Ph. 0651-6555611)
Dr. Abrar Ahmad, Head, Associate Professor, Ranchi University, Ranchi.

Ref: **Date:** 26/08/2025

Meeting of Board of Studies

A meeting of Board of Studies was convened in the office of the Head of University Department of Mathematics, Ranchi University, Ranchi on 26/08/2025 at 02:30 PM.

The agenda of the meeting was to approve the draft syllabus of FYUG Program in Statistics & NEP Post Graduate in Statistics under Ranchi University, Ranchi.

After detailed discussion, the Board of Studies have finalized and approved the draft syllabus of FYUG Program in Statistics & NEP Post Graduate in Statistics under Ranchi University, Ranchi.

Chairman:

1. Dr. Abrar Ahmad
   Head University Department of Mathematics
   Ranchi University, Ranchi.

2. **External members:**
   i. Dr. Vanshi Dhar
   Retired Prof in Statistics, BAU, Ranchi
   ii. Dr. K. B. Panda
   Prof in Statistics, Department of Statistics, C.U.J. Ranchi
   iii. Dr. Sunit Kumar
   Associate Professor in Statistics
   Central University of South Bihar, Gaya.
   iv. Dr. Raman Kumar Das, Associate Professor
   Department of Mathematics, St. Xavier's College, Ranchi
   v. Prof P.K. Singh, Assistant Professor
   Department of Statistics
   Jamshedpur Cooperative College, Kolhan University, Chaibasa.
   vi. Dr. Shivam Mishra, Assistant Professor
   Department of Agricultural Statistics
   Birsa Agricultural University, Ranchi
   vii. Mr. Rakesh Mishra, Assistant Professor
   Department of Mathematics & Statistics, St. Xavier's College, Ranchi.

3. **Internal Members:**
   i. Dr. Ashsih Kumar Jha
   University Department of Mathematics, Ranchi University, Ranchi
   ii. Mrs. Rimil Nidhi Bhuinyan
   University Department of Mathematics, Ranchi University, Ranchi
   iii. Dr. Sheet Nihal Topno
   University Department of Mathematics, Ranchi University, Ranchi
   iv. Mr. Amit Bara
   University Department of Mathematics, Ranchi University, Ranchi

Head
Department of Mathematics,
Ranchi University, Ranchi

Dr. Abrar Ahmad
Chairman
Univ. Department of Mathematics
Ranchi University, Ranchi

Head
Department of Mathematics,
Ranchi University, Ranchi

Approval by the Members of the NEP Implementation and Monitoring Committee of Ranchi University, Ranchi

The prepared Curriculum of the Master's Degree has been approved by the NEP Implementation and Monitoring Committee of R.U., duly forwarded by the Head of the Department; it will be offered to the Students of the 1-year and 2-year Postgraduate Programme. It is implemented from the 1st Semester of the Academic Session 2025-26 and onwards.

Member Secretory

Contents

COURSE STRUCTURE FOR PG **'PG DIPLOMA/ COURSEWORK ONLY/ COURSEWORK WITH RESEARCH/ RESEARCH ONLY'**

Table 1: Credit Framework for Two-Year Postgraduate Programme [Total Credits = 80]

Academic Level	**Level of Courses**	**Semester**	**Coursework** Level 400	**Coursework** Level 500	**Research Preparedness**	**Research thesis/ Project/ Patent**	**Total Credits**
YEAR 1							
Level 6	**Coursework**	**I**	**4+4+4**	**4+4**	**---**	**---**	**20**
		II	**4+4+4**	**4+4**	**---**	**---**	**20**
YEAR 2:	**Exit Point: Having an Internship of 4 credits Exit allowed with PG Diploma Certificate**						
Level 6.5	**Coursework**	**III**	**---**	**4+4+4+4+4**	**---**	**---**	**20**
		IV	**---**	**4+4+4+4+4**	**---**	**---**	**20**
OR							
Level 6.5	**Coursework + Research**	**III**	**---**	**4+4+4+4+4**	**---**	**---**	**20**
		IV	**---**	**---**	**20**		**20**
OR							
Level 6.5	**Research**	**III**	**---**	**---**	**20**	**---**	**20**
		IV	**---**	**---**	**---**	**20**	**20**
Total credits of P.G. Programme = **80**							

Note: **Every student has to take any one Value-added course of 2-credits compulsorily in the 1st Semester of the PG programme**.

HIGHLIGHTS OF NEP PG CURRICULUM

CREDIT OF COURSES

The term 'credit' refers to the weightage given to a course, usually in terms of the number of instructional hours per week assigned to it. The workload relating to a course is measured in terms of credit hours. It determines the number of hours of instruction required per week over a semester (minimum 15 weeks).

a) One hour of teaching/ Lectures or two hours of laboratory /practical work will be assigned per class/interaction.
   One credit for Theory = 15 Hours of Teaching
   One credit for Practicum = 30 Hours of Practical work
   One credit for Internship = 02 Weeks of Practical experience

b) For credit determination, instruction is divided into three major components:
   Hours (L) – Classroom Hours of one hour duration.
   Tutorials (T) – Special, elaborate instructions on specific topics of one hour duration
   Practical (P) – Laboratory or field exercises in which the student has to do experiments or other practical work of a two-hour duration.

   Internship – For the Exit option after 1st year of the 2-year P.G. Programme for the award of P.G. Diploma, Level 6.5, Students can either complete two 4-week internships worth 2 credits each or one 8-week internship for all 4 credits. This practical experience connects academic learning with real-world applications, offering valuable exposure to professional environments in their fields of study

PG CURRICULUM

1. The PG Curriculum will be either of 1-year duration for students who studied the four-year UG Programme (FYUGP) or a 2-year duration for students who studied a three-year UG programme from a CBCS/LOCF/FYUGP Curriculum.
2. There is a flexible mode in the PG programme offered to the students of Ranchi University, Ranchi. The total credit for any semester will be 20 credits.
3. **Two-year PG curriculum:** The First year of the PG curriculum offers coursework only. There will be 3 courses at level 400 and 2 courses at level 500 in the first and the second semesters of any 2-year PG programme.
4. **One-year PG curriculum:** The Courses in the 1-year PG programme and the second year of the 2-year PG programme are the same.
   a. **Course work only**: There will be 5 courses at level 500 of 4 credits each in every semester for the coursework offered in the programme.
   b. **Course work and Research**: There will be 5 courses at the level 500 bearing 4 credits each in the first semester of a 1-year PG or in the third semester of a 2-year PG. There will be Research work offered in the next semester for this mode offered in the programme. The eligibility for this mode is available in the NEP PG curriculum of Ranchi University, Ranchi.
   c. **Research work only**: The eligible student will be offered this mode to conduct extensive research under the supervision of a guide. Each semester will be equivalent to 20 credits. The selection of a candidate for the research mode will depend upon the eligibility of the student, availability of the guide and seat in the department/institution of Ranchi University, Ranchi.

PROMOTION CRITERIA

Two Years Post-graduation programme having coursework only:

i. Each course shall be of **100 marks** having two components: **30 marks for Sessional Internal Assessment (SIA), conducted by the Department/College and 70 marks for the End Semester University Examination (ESUE), conducted by the University**.
ii. The marks of SIA shall further break into, 20 for Internal Written Examinations, 05 for Assignment/ Project/Seminar presentation and 05 for attendance in the classroom lectures and other activities of the Department/College.

iii. The Requisite Marks obtained by a student in a particular subject will be the criteria for promotion to the next Semester.
iv. There shall be two written internal examinations, each of 1 hour duration and each of 20 marks, in a semester out of which the '**Better One out of Two**' shall be taken for computation of marks under SIA.
v. It is compulsory to pass the Mid-Semester examination. If someone fails in the Mid-Semester exam of a particular course, he/she has to retake both the Mid-Semester and End-Semester exams next year, regardless of how many marks he/she obtained in the End-Semester Examination.
vi. In case a student fails to secure pass marks in End Semester Examination, then he/she has to appear only in End Semester Examination of the following Sessions within the period of Upper Limit of Four Years and the Marks of Mid Semester will be carried for the preparation of result.
vii. Students' final marks and the result will be based on the marks obtained in Mid Semester and End Semester Examination taken together.
viii. The pass marks in the programme will be 45% of the total marks obtained in each Core/ Elective/ Other Courses offered.
ix. In absolute terms of marks obtained in a course, **a minimum of 28 marks is essential in the ESUE** and **a minimum of 17 marks is to be secured in the SIA** to clear the course. In other words, a student shall have to pass separately in the ESUE and in the SIA by securing the minimum marks prescribed here.
x. Every candidate seeking to appear in the ESUE shall be issued an Admit Card by the University. **No candidate will be permitted to appear in the examination without a valid admit card.**
xi. A candidate shall be permitted to proceed in next Semester (2^{nd}, 3^{rd} and 4^{th}) **provided he/she has passed at least in <u>3 courses</u> out of 5 courses** in the respective semester in theory and practical/ project courses taken together.
xii. A student will have to clear all his papers within a maximum of Four Years of duration to qualify for the degree.

However, it will be necessary to procure pass marks in each of the papers before completion of the programme.

VALUE-ADDED COURSES

1. The Value-added course will be of **2 credits** to be covered during the first semester.
2. There will be objective-type questions asked in the End Semester University Examination (ESUE).
3. There will be an OMR-based examination and the correct answer is to be marked by a black ballpoint pen only on the OMR sheet provided by the University.
4. For the **50 Marks Examination,** the student will be provided **two hours** to mark their responses.
5. Students are not allowed to choose or repeat courses already undergone at the undergraduate level in the proposed major and minor streams.
6. The performance in this course will not influence the SGPA or CGPA of the PG Programme where the student is registered to obtain the Master's Degree. <u>However, it will be mandatory to secure minimum pass marks in the course before exit from the PG Programme.</u>
7. If the student fails to secure the minimum pass marks in the Value-added course in the first semester, he may appear in the examination of the said course with the following batch of the next session.
8. The student may appear in the examination of the said course further if could not clear the course in the following attempt, subject to the date of validation of the Registration.

The existing Regulations of the PG Curriculum of Ranchi University, Ranchi, shall govern any matters not mentioned above.

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AIMS OF MASTER'S DEGREE PROGRAMME IN STATISCTICS

The aim of Master's degree programme in Statistics is intended to provide:

1. Cultivating logical reasoning skills and fostering a capacity for statistical thinking.
2. Providing a comprehensive understanding of key statistical models and analytical tools necessary for addressing complex data analysis problems.
3. Offering exposure to a range of statistical software packages, enhancing proficiency in both analysis and programming.
4. Developing effective communication and technical writing abilities to articulate statistical concepts clearly, both orally and in writing, using appropriate terminology for diverse audiences.
   Nurturing skills in collaborative teamwork across disciplines and instilling principles of professional accountability and ethics.

PROGRAMME LEARNING OUTCOMES

The broad Learning Outcomes of Master's degree programme in Statistics are:

1. Knowledge Domain: Demonstrate comprehension of the theoretical and computational underpinnings of probability theory, inference, sample surveys, multivariate techniques, regression analysis, and stochastic processes, emphasizing their significance in data analytics.
2. Problem Analysis: Apply principles of scientific inquiry and critical thinking to solve problems and make informed decisions, systematically finding, analysing, evaluating, and applying information.
3. Presentation and Interpretation of Data: Exhibit proficiency in manipulating, visualizing, and computing standard statistical summaries from data sets.
4. Modern tool usage: Acquire proficiency in selecting and employing appropriate methods, procedures, resources, and computing tools such as Excel, MATLAB, SPSS, and R, while understanding their limitations.
5. Technical Skills: Utilize modelling, simulation, and data analysis tools to address real-world problems, generating solutions capable of predicting and explaining complex phenomena.
6. Analyse ethical issues relevant to academia, profession, and research, adhering to ethical norms in data analysis and research practices.
7. Communication: Effectively communicate statistical concepts and activities to peers and society, including comprehension of writing effective reports, designing documentation, and delivering presentations.
8. Project Management: Apply statistical principles effectively in managing projects both individually and within diverse teams, fostering multidisciplinary collaboration.
9. Lifelong Learning: Demonstrate the ability to independently explore and learn statistical tools, adapting to technological advancements and continuing professional development.

The Courses in One Year P.G. Programme and in the Second year of Two years P.G. Programme are Common.

Table 2: Semester-wise Course Code and Credit Points

Sem	Core, AE/ GE/ DC/ EC & Compulsory FC Courses				Examination Structure		
	Paper	Paper Code	Credit	Name of Paper	Mid Semester Evaluation (F.M.)	End Semester Evaluation (F.M.)	End Semester Practical/ Viva (F.M.)
I	Foundation Course	FCSTA121	4	Multivariate Statistical Analysis	30	70	----
	Core Course	CCSTA122	4	Bayesian Inference	30	70	----
	Core Course	CCSTA123	4	Research Methodology	30	70	----
	Core Course	CCSTA124	4	Advanced Linear Algebra	30	70	----
	Practicals on Core	CPSTA125	4	Practical	----	----	100
II	Core Course	CCSTA221	4	Design and analysis of experiments	30	70	----
	Core Course	CCSTA222	4	Stochastic Processes & Queuing Theory	30	70	----
	Core Course	CCSTA223	4	Mathematical Analysis	30	70	----
	Core Course	CCSTA224	4	Advanced Statistical Inference	30	70	----
	Practicals on Core	CPSTA225	4	Practical	----	----	100
III	Core Course	ECSTA321	4	IKS in Statistics	30	70	----
	Skill Enhancement Course	CCSTA322	4	Biostatistics	30	70	----
	Core Course	CCSTA323	4	Measure Theory & Probability	30	70	----
	Core Course	CCSTA324	4	Linear Models & Regression Analysis	30	70	----
	Practicals on Core	CPSTA325	4	Practical	----	----	100
IV	Elective	ECSTA401	4	A. Machine Learning using Python B. Financial Statistics A. Applied Stochastic Processes	30	70	----
	Elective	ECSTA402	4	A. Advanced Statistical Computing & Data Mining B. Econometrics & Time Series Analysis B. Actuarial Statistics	30	70	----
	Core Course	CCSTA403	4	Order Statistics	30	70	----
	Practicals on Elective	EPSTA404	4	A. Practical A B. Practical B C. Practical C	----	----	100
	PROJECT	PRSTA405	4	Dissertation/ Project Work/ Teaching Aptitude	----	----	100

Note:

1. **Every student has to take any one Value-added course of 2 credits compulsorily in the 1st Semester of the PG programme.**
2. **Either One Internship of 4 credits or Two Internships of 2 credits each is required before opting for the 'Exit' option after the first year of the P.G. Programme.**

INSTRUCTION TO QUESTION SETTER

SEMESTER INTERNAL EXAMINATION (SIE):

Marks Weightage of a Course: Each non-practical/non-project course shall be of **100 marks** having two components: **70 marks shall be assigned to the End Semester University Examination (ESUE), conducted by the University, and, 30 marks for Sessional Internal Assessment (SIA), conducted by the Department/College**.

The marks of SIA shall further be divided into 20 for Internal Written Examinations, 05 for Assignment/Project/Seminar presentation, and 05 for attendance at classroom lectures and other activities of the Department/College. There shall be two written internal examinations, each of 1-hour duration and each of 20 marks, in a semester, out of which the **'Better One out of Two'** shall be taken for computation of marks under SIA.

In absolute terms of marks obtained in a course, **a minimum of 28 marks is essential in the ESUE and a minimum of 17 marks is to be secured in the SIA to clear the course**. In other words, a student shall have to pass separately in the ESUE and in the SIA by securing the minimum marks prescribed here.

A. (SIE 20+5+5=30 marks):

There will be a uniform pattern of questions for mid-semester examinations in all the courses and across all the programmes. There will be **two** groups of questions in 20-mark written examinations. **Group A is compulsory** and will contain five questions of **very short answer type** consisting of 1 mark each. **Group B will contain descriptive type five** questions of five marks each, out of which any three are to be answered. Department may conduct Sessional Internal Examinations in other format as per needs of the course.

The Semester Internal Examination shall have three components. (a) One Semester Internal Assessment Test (SIA) of 20 Marks, (b) Assignment/Project/ Seminar Presentation of 5 marks (c) Class Attendance Score (CAS) of 5 marks.

Conversion of Attendance into score may be as follows:

Attendance Upto 45%, 1mark; 45<Attd.<55, 2 marks; 55<Attd.<65, 3 marks; 65<Attd.<75, 4 marks; 75<Attd, 5 marks.

END SEMESTER UNIVERSITY EXAMINATION (ESUE):

A. (ESUE 70 marks):

There will be a uniform pattern of questions for all the courses and all the programmes. There will be **two** groups of questions. **Group A is compulsory** and will contain two questions. **Question No.1 will be very short-answer type** consisting of five questions of 1 mark each. **Question No.2 will be a short-answer type** of 5 marks. **Group B will contain descriptive type six** questions of fifteen marks each, out of which any four are to be answered. The questions will be so framed that examinee could answer them within the stipulated time.

[**Note:** There may be subdivisions in each question asked in Theory Examinations]

B. (ESUE 100 marks):

Practical/ Project courses would also be of 100 marks but there **shall be no internal written examinations** of the type specified above. The total 100 marks will have two components: **70 marks for the practical ESUE and 20 marks for the Viva-voce examination** conducted during the ESUE to assess the applied and practical understanding of the student.

The written component of the project (**Project Report**) shall be of **70 marks and 20 marks will be for the Viva-voce examination** jointly conducted by an external examiner, appointed by the University, and the internal supervisor/ guide.

10 marks will be assigned on the cumulative assessment of the examinee during the semester and will be awarded by the department/faculty concerned.

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FORMAT OF QUESTION PAPER FOR MID/ END SEMESTER EXAMINATIONS

Question format for **20 Marks**:

Subject/ Code

F.M. =20 **Time**=1Hr. Exam Year

General Instructions:

i. **Group A** carries very short answer type compulsory questions.
ii. **Answer 1 out of 2** subjective/ descriptive questions given in **Group B**.
iii. Answer in your own words as far as practicable.
iv. Answer all sub parts of a question at one place.
v. Numbers in right indicate full marks of the question.

Group A

1. [5x1=5]
   i. ....
   ii. ....
   iii. ....
   iv. ....
   v. ....
2. .... [5]

Group B

3. .... [10]
4. .... [10]

Note: There may be subdivisions in each question asked in Theory Examination.

Question format for **70 Marks**:

Subject/ Code

F.M. =70 **Time**=3HrS. Exam Year

General Instructions:

i. **Group A** carries very short answer type compulsory questions.
ii. **Answer 4 out of 6** subjective/ descriptive questions given in **Group B**.
iii. Answer in your own words as far as practicable.
iv. Answer all sub parts of a question at one place.
v. Numbers in right indicate full marks of the question.

Group A

1. [5x1=5]
   i. ....
   ii. ....
   iii. ....
   iv. ....
   v. ....
2. .... [5]

Group B

3. .... [15]
4. .... [15]
5. .... [15]
6. .... [15]
7. .... [15]
8. .... [15]

Note: There may be subdivisions in each question asked in Theory Examination.

SEMESTER I

I. FOUNDATION COURSE [FCSTA121]
MULTIVARIATE STASTICAL ANALYSIS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives & Learning Outcomes:

This course will enable the students to:

1. The understanding of basic concepts associated with Multivariate Normal Distributions and their properties with special emphasis on Bivariate Normal Distribution.
2. Analysing Multivariate data using data reduction techniques like Principal Component Analysis, Factor Analysis.
3. Classification method namely Discriminant Analysis.
4. Analysing Multivariate data using data reduction techniques like Principal Component Analysis, Factor Analysis.
5. Classification method namely Discriminant Analysis.
6. Understand about fundamentals concepts of stochastic processes and Use notions of long-time behaviour including transience, recurrence and equilibrium in applied situations.
7. Testing of hypothesis using Non-Parametric test like Median test, Run test, Kruskal Wallis test etc.

Course Contents:

UNIT 1: Bivariate Normal Distribution (BVN): p.d.f. of BVN, properties of BVN, marginal and conditional p.d.f. of BVN.

UNIT 2: Multivariate Data: Random Vector: Probability mass/density functions, Distribution function, Mean vector & Dispersion matrix, Marginal & Conditional distributions.

UNIT 3: Multivariate Normal distribution and its properties. Sampling distribution for mean vector and variance- covariance matrix. Multiple and partial correlation coefficient and their properties.

UNIT 4: Applications of Multivariate Analysis: Discriminant Analysis, Principal Components Analysis and Factor Analysis. MANOVA.

UNIT 5: Non-parametric Tests: Introduction and Concept, Test for randomness based on total number of runs, Empirical distribution function. Kolmogrov Smirnov test for one sample, Sign tests- one sample and two samples, Wilcoxon-Mann-Whitney test, Kruskal-Wallis test.

Reference Books:

1. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rd Edn., John Wiley
2. Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley.
3. Kshirsagar, A.M. (1972): Multivariate Analysis, 1stEdn. Marcel Dekker.
4. Johnson, R.A. and Wichern, D.W. (2007): Applied Multivariate Analysis, 6th Edn., Pearson & Prentice Hall
5. Mukhopadhyay, P.: Mathematical Statistics.
6. Gun A.M., Gupta M.K.: Das Gupta. B. (2005), Fundamentals of Statistics, Vol. I, World Press, Calcutta.
7. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons.

II. CORE COURSE [CCSTA122]
BAYESIAN INFERENCE

Marks: 30 (MSE: 20 Th. 1Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE :28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives & Learning Outcomes:

1. Understand the Bayesian approach to statistical inference.
2. Specify appropriate prior distributions and interpret posterior distributions.
3. Perform Bayesian estimation and hypothesis testing.
4. Compare Bayesian and frequentist approaches.
5. Use computational methods (like MCMC) to solve complex Bayesian problems.

Course Contents:

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

UNIT 2: Classes of Prior Distributions. Conjugate Families for One Parameter Exponential Family Models, Models admitting sufficient statistics of fixed dimension.

UNIT 3: 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 4: Prior and posterior odds. Bayes factor. Lindley's Paradox. Various types of testing hypothesis problems.

UNIT 5: 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, 2nd ed., Springer Verlag.

III. CORE COURSE [CCSTA123]
RESEARCH METHODOLOGY

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives & Learning Outcomes:
This course will enable the students to:
1. Understand the fundamentals of research and its methodologies.
2. Formulate research problems and hypotheses.
3. Design appropriate research strategies.
4. Understand methods of data collection and sampling.
5. Analyze data using statistical tools.
6. Interpret and communicate research findings effectively.
7. Prepare structured research reports and project proposals

Course Contents:

UNIT 1: Meaning and objectives of research, Types of research: basic, applied, quantitative, qualitative, Scientific method and research process, Role of statistics in research Identifying and defining research problems, Review of literature, Research questions and objectives, Formulation of hypotheses, Types of hypotheses: null and alternative

UNIT 2: Concepts of research design, features of a good design, Types of research design: exploratory, descriptive, experimental, cross-sectional, longitudinal. Control, randomization, replication

UNIT 3: Types of data: primary vs secondary, qualitative vs quantitative, Data collection tools: questionnaires, interviews, observation. Construction of questionnaires and schedules. Scaling techniques: nominal, ordinal, interval, ratio. Reliability and validity

UNIT 4: Editing, coding, tabulation. Descriptive statistics: tables, charts, measures of central tendency and dispersion. Inferential statistics: estimation, testing of hypotheses. Use of software (e.g., Excel, R, SPSS) in data analysis

UNIT 5: Interpretation of results, Structure of a research report, Referencing styles: APA/MLA, Common errors in report writing, Use of LaTeX or Word for writing research reports.

Suggested Readings:

1. R. Kothari & Gaurav Garg, Research Methodology: Methods and Techniques
2. Ranjit Kumar, Research Methodology: A Step-by-Step Guide for Beginners
3. Panneerselvam R., Research Methodology
4. Jaspal Singh, Research Methodology and Statistical Techniques

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IV. CORE COURSE [CCSTA124]
ADVANCED LINEAR ALGEBRA

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives & Learning Outcomes:

This course will enable the students to:

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. Course Content

Course Contents:

UNIT 1: 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 2: 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 3: 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 4: 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.

UNIT 5: 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.

Reference 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.

V. CORE COURSE [CCSTA125]
PRACTICAL

Marks: 100 (ESE Pr: 6 Hrs) = 100	**Pass Marks = 45**

(Credits: Theory-04, 60 Hours)

Instruction to Question Setter for

End Semester Examination (ESE Pr):
There will be one Practical Examination of 6 Hrs duration. Evaluation of Practical Examination may be as per the following guidelines:
Experiment/Lab work = 70 marks
Practical record notebook = 05 marks
Attendance = 05 marks
Viva-voce = 20 marks

Course Objective:

1. Analysing Multivariate data using data reduction techniques like Principal Component Analysis, Factor Analysis.
2. Classification method namely Discriminant Analysis.
3. Testing of hypothesis using Non-Parametric test like Median test, Run test, Kruskal Wallis test etc.

Practicals:

UNIT 1: Principal Component Analysis (PCA) and Factor Analysis

Computation of principal components from a given data set. Determination of number of components using eigenvalues, scree plot, and variance explained. Application of PCA for data reduction and interpretation. Conducting Factor Analysis: extraction of factors (principal component, principal axis). Rotation methods (varimax, quartimax) and interpretation of rotated factor loadings. Computation of factor scores and their application. Software Practice: PCA and Factor Analysis using R/SPSS/Python.

- Assignments/Problems:
  - Reduce a dataset into fewer dimensions using PCA.
  - Perform Factor Analysis for social science/healthcare data and interpret factors.

UNIT 2: Discriminant Analysis

Construction of discriminant functions for two-group and multi-group cases. Computation of classification functions and classification of new observations. Calculation of Wilks' Lambda, canonical correlations, and group centroids. Evaluation of classification accuracy (hit ratio, confusion matrix). Cross-validation methods in discriminant analysis. Software Practice: Carrying out Discriminant Analysis in R/SPSS/Python.

- Assignments/Problems:
  - Classify individuals into groups based on multivariate data.
  - Compare classification accuracy of discriminant function with other methods.

UNIT 3: Non-Parametric Methods

Application of Chi-square tests (goodness of fit, test of independence). Rank-based tests: Mann–Whitney U test, Wilcoxon signed-rank test. Kruskal–Wallis test and Friedman test for k-sample problems. Kolmogorov–Smirnov one-sample and two-sample tests. Spearman's rank correlation and Kendall's tau. Software Practice: Performing non-parametric tests using SPSS/R.

- Assignments/Problems:
  - Test hypotheses using rank-based methods.
  - Apply chi-square test on real categorical datasets.
  - Use non-parametric correlation to measure association in ordinal data.

UNIT 4: Questionnaire Preparation for Research

Principles of designing a research questionnaire. Constructing questions: open-ended, closed-ended, Likert scale, semantic differential scale. Preparing a draft questionnaire for a given research problem (e.g., health, psychology, social science, management). Conducting pilot testing and refining the questionnaire. Assessing reliability (Cronbach's alpha, split-half method). Assessing validity (content, construct, criterion-related).

- Assignments/Problems:
  - Prepare a questionnaire for a selected research topic.
  - Test the reliability and validity of the designed questionnaire using SPSS/R.

UNIT 5: Bivariate and Multivariate Normal Distribution

Verification of properties of bivariate normal distribution using data. Computation of probabilities for bivariate normal distribution. Derivation of marginal and conditional distributions from joint distribution. Estimation of parameters: mean vector and covariance matrix. Simulation of multivariate normal data using software. Application of multivariate normal distribution in regression, PCA, and hypothesis testing. Software Practice: Multivariate normal simulation and analysis in R/Python.

- Assignments/Problems:
  - Compute conditional distributions and correlations.
  - Simulate data from multivariate normal distribution and analyse it.

Note:

1. MS Excel/R/SPSS/Python or Any Statistical Software and Computer System may be provided by the Institution.
2. However, Use of Smartphone or Web is restricted in the Examination.

Reference Readings:

1. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rd Edn., John Wiley
2. Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley.
3. Kshirsagar, A.M. (1972): Multivariate Analysis, 1stEdn. Marcel Dekker.
4. Johnson, R.A. and Wichern, D.W. (2007): Applied Multivariate Analysis, 6th Edn., Pearson & Prentice Hall
5. Mukhopadhyay, P.: Mathematical Statistics.
6. Gun A.M., Gupta M.K.: Das Gupta. B. (2005), Fundamentals of Statistics, Vol. I, World Press, Calcutta.
7. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons.

SEMESTER II

I. CORE COURSE [CCSTA221]
DESIGN AND ANALYSIS OF EXPERIMENTS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives & Learning Outcomes:

This course will enable the students to:

1. The fundamental concepts of design of experiments.
2. The concepts of completely randomized design, Randomized block design and Latin square design
3. The concepts of balanced incomplete block design,
4. Total and partial confounded factorial design and identify the effects of different factors and their interactions and analyze factorial experiments.
5. The applications of completely randomized design, Randomized block design and latin square design,
6. The applications of balanced incomplete block design,
7. Total and partial confounded factorial design and identify the effects of different factors and their interactions and analyze factorial experiments on real life data.

Course Contents:

UNIT 1: Experimental designs: Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks.

UNIT 2: Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model and statistical analysis, relative efficiency, analysis with missing observations.

UNIT 3: Incomplete Block Designs: Balanced Incomplete Block Design (BIBD) – parameters, relationships among its parameters, incidence matrix and its properties. Symmetric BIBD, Resolvable BIBD, Affine Resolvable BIBD, Intra Block analysis, complimentary BIBD, Residual BIBD, Dual BIBD, Derived BIBD.

UNIT 4: Factorial experiments: advantages, notations and concepts, 2^2, 2^3 and 3^2 factorial experiments, design and analysis.

UNIT 5: Total and Partial confounding for 2^n ($n \leq 5$), 3^2 and 3^3. Factorial experiments in a single replicate.

Reference Books:

1. Weisberg, S. (2005). Applied Linear Regression (Third edition). Wiley.
2. Wu, C. F. J. And Hamada, M. (2009). Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.
3. Renchner, A. C. And Schaalje, G. B. (2008). Linear Models in Statistics (Second edition), John Wiley and Sons.
4. Fundamentals of Applied Statistics, S. C. Gupta & V.K. Kapoor
5. Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House.
6. Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd.
7. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8th Edn. World Press.
8. Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley.
9. Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.
10. Dey Aloke (1986) : Theory of Block Design, Wiley Eastern.

II. CORE COURSE [CCSTA222]
STOCHASTIC PROCESSES & QUEUING THEORY

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives & Learning Outcomes:

This course will enable the students to:

1. Understand about fundamentals concepts of stochastic processes and Use notions of long-time behaviour including transience, recurrence and equilibrium in applied situations.
2. Understand about Markov processes, Markov chains, Stability of Morkov chains and Construct transition matrices for Markov dependent behaviour and summarize process information.
3. Understand the principles and objectives of model building based on Markov Chains.
4. Understand the concept of Queuing systems, Random walk and Classical ruin problem.

Course Contents:

UNIT 1: Probability Distributions: Generating functions, Bivariate probability generating function. Stochastic Process: Introduction, Stationary Process.

UNIT 2: Markov Chains: Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities. Generalization of independent Bernoulli trials, classification of states and chains, stability of Markov system, graph theoretic approach.

UNIT 3: Poisson Process: postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, birth and death process, pure death process.

UNIT 4: Queuing System: General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof).

UNIT 5: Gambler's Ruin Problem: Classical ruin problem, expected duration of the game.

Reference Books:

1. Medhi, J. (2009): Stochastic Processes, New Age International Publishers.
2. Basu, A.K. (2005): Introduction to Stochastic Processes, Narosa Publishing.
3. Bhat, B.R. (2000): Stochastic Models: Analysis and Applications, New Age International Publishers.
4. Taha, H. (1995): Operations Research: An Introduction, Prentice- Hall India.
5. Feller, William (1968): Introduction to probability Theory and Its Applications, Vol I, 3rd Edition, Wiley International.

III. CORE COURSE [CCSTA223]
MATHEMATICAL ANALYSIS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course objectives & learning outcomes:
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.

Course Contents:

UNIT 1: 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 2: 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 3: Properties of complex numbers, Region in complex plane, Limit, continuity and differentiability of function of complex variables

UNIT 4: Analytic function, Contour integration, Cauchy integral formula, Liouville's theorem, Fundamental theorem of Algebra.

UNIT 5: 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).

IV. CORE COURSE [CCSTA224]
ADVANCED STATISTICAL INFERENCE

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objective & Learning outcomes

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.

Course Contents:

UNIT 1: Consistency and asymptotic relative efficiency of estimators, Consistent asymptotic normal (CAN) estimator, Method of maximum likelihood, CAN estimator for one parameter Cramer family.

UNIT 2: 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 3: 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 4: Sequential tests-SPRT and its properties, Wald's fundamental identity, OC and ASN functions. Sequential estimation

UNIT 5: 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.

V. CORE COURSE [CPSTA225]
PRACTICAL

Marks: 100 (ESE Pr: 6 Hrs) = 100	Pass Marks = 45

(Credits: Theory-04, 60 Hours)

Practical Paper Syllabus

(Based on Design of Experiments)

UNIT 1: Experimental Designs

Construction of fertility contour maps and uniformity trials using data. Determination of optimum size and shape of plots and blocks. Illustration of experimental error and principles of randomization, replication, and local control.

- Exercises/Problems:
  - Preparing layouts for field trials.
  - Analysing variation due to plot size/shape.

UNIT 2: Basic Designs (CRD, RBD, LSD)

Layout and randomization of CRD, RBD, LSD. Analysis of variance (ANOVA) for CRD, RBD, and LSD. Calculation of efficiency factors. Handling missing data in basic designs.

- Software Practice: ANOVA in R/SPSS/Excel.
- Exercises/Problems:
  - Conducting statistical analysis for each design.
  - Comparing efficiencies of designs.

UNIT 3: Incomplete Block Designs (IBD)

Construction of incidence matrices for BIBDs. Verification of parameter relationships in BIBD. Intra-block analysis and efficiency factors. Analysis of resolvable, symmetric, residual, and dual BIBDs.

- Exercises/Problems:
  - Building incidence matrices and verifying properties.
  - Solving intra-block analysis numerically.

UNIT 4: Factorial Experiments

Construction and analysis of 2^2, 2^3, 3^2factorial experiments. Estimation of main effects and interaction effects.

- Exercises/Problems:
  - Analysing factorial experiments manually and via software.
  - Interpretation of interaction plots.

UNIT 5: Confounding in Factorial Designs

Total and partial confounding in 2^n (n≤5) Layout and analysis of factorial experiments with confounding. Factorial experiments in single replicate situations.

- Exercises/Problems:
  - Designing and Analysing confounded factorial experiments.
  - Demonstration with software outputs.

Note:

1. MS Excel/R/SPSS/Python or Any Statistical Software and Computer System may be provided by the Institution.
2. However, Use of Smartphone or Web is restricted in the Examination.

Reference Books:

1. Weisberg, S. (2005). Applied Linear Regression (Third edition). Wiley.
2. Wu, C. F. J. And Hamada, M. (2009). Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.
3. Renchner, A. C. And Schaalje, G. B. (2008). Linear Models in Statistics (Second edition), John Wiley and Sons.
4. Fundamentals of Applied Statistics, S. C. Gupta & V.K. Kapoor
5. Gujarati, D. and Sangeetha, S. (2007): Basic Econometrics, 4th Edition, McGraw Hill Companies.
6. Kendall M.G. (1976): Time Series, Charles Griffin.

SEMESTER III

I. CORE COURSE [CCSTA321]
IKS IN STATISTICS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives & learning Outcomes

1. To introduce students to the evolution of statistical thinking within the Indian Knowledge System(IKS).
2. To understand the role of statistics in ancient Indian texts, astronomy, architecture, medicine, economics and governance.
3. To explore indigenous methods of data collection, inference, and measurement.
4. To connect traditional statistical wisdom with modern statistical theories and applications.

Course Contents:

UNIT 1: Introduction to Indian Knowledge System: philosophy, domains, and interdisciplinary nature. Early evidence of statistical thought in Indian civilization (Indus Valley inscriptions, trade records, population counts).

UNIT 2: Concept of Ankana (enumeration), Parimana (measurement), Ganita (computation) in Vedic and classical texts. Role of mathematics and Statistics in Sulbasutras and Vedang Jyotisha.

UNIT 3: Statistics in ancient Indian texts: enumeration and combinatorics in Pingala's Chandas Shastra (prosody and binary system). Use of probability concepts in games of dice (Aksha Shastra, Mahabharata references).

UNIT 4: Statistical thinking in Kautilya's Arthshastra – census, revenue, estimation, population surveys, and economic planning

UNIT -V: Quantification and inference in Ayurveda (Charaka Samhita and Sushruta Samhita): clinical observations, data based diagnosis.

Reference Books:

1. K.V.Sarma, A History of the Kerala School of Hindu Astronomy.
2. S. Balachandra Rao, Indian Mathematics and Astronomy: Some Landmarks.
3. Debiprasad Chattopadhyaya, History of Science and Technology in Ancient India.
4. Michel Danino, Indian Knowledge Systems.
5. Original passages from Arthashastra, Pingala's Chandas Shastra, Charaka Samhita, and Sulbasutras.

II. SKILL ENHANCEMENT COURSE [ECSTA322]
BIOSTATISTICS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives& Learning outcomes

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

Course Contents:

UNIT 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. 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.

UNIT 2: 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 3: 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.

UNIT 4: 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 5: 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/codominant cases), Approach to equilibrium 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.

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

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III. CORE COURSE [CCSTA323]
MEASURE THEORY & PROBABILITY

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives & Learning Outcomes:

This course will enable the students to:

1. Understand the basic concepts of measure and integration theory.
2. Understand the basic theory on the basis of examples and applications.
3. Use abstract methods to solve problems and to use a wide range of references and critical thinking.
4. Use weak and strong law of large numbers in statistical theory

Course Contents:

UNIT 1: Fields, sigma-fields and generators, semi-fields, Borel sigma-field on R. Monotone classes, monotone class theorem, pi-lambda theorem. Measures, finite, sigma-finite measures. Probability measures, properties. Independence of events, Borel-Cantelli lemmas. Measurable functions and properties, Generated sigma-fields. Induced measures. Compositions. Examples.

UNIT 2: Product sigma-fields, Borel sigma-field on Euclidean spaces. Extensions of measures, Caratheodory's theorem (statement). Lebesgue measure on R and R_k: construction, properties.

UNIT 3: Random variables and vectors, probability distributions, distribution functions. Convergence in measure, almost everywhere and their connection.

UNIT 4: Integration: simple, nonnegative, general measurable functions, integrability, Monotone Convergence Theorem, Dominated Convergence Theorem, Fatou's lemma. Change of variables. L_p spaces, Holder's and Minkowski's inequalities. Expectations, Moment inequalities – Chebychev, Markov, Liapunov, Minkowski, Cauchy-Schwartz, Kolmogorov and Jensen. Generating functions.

UNIT 5: Absolute continuity and singularity of measures. Radon-Nikodym Theorem (Statement). Discrete and absolutely continuous distributions. Lebesgue's differentiation theorem (statement), probability densities. Strong law of large numbers, Central limit theorem – Lindberg-Levy, Liapunov & Lindberg -Feller.

Reference Readings:

1. Ash, Robert, (1972), Real Analysis and Probability, Academic Press.
2. Barra, G.D. (1981), Measure Theory and Integration, New Age International (P)Ltd. Publisher, New Delhi.
3. Bhat, B.R. (2014). Modern Probability Theory, 04^{th} edition, New Age International.
4. Bilingsley. P. (2012) , Measure Theory and Probability , 04^{th} edition . Wiley.
5. Rao, C.R. (2001), Linear Statistical Inference and its Applications, 02^{nd} edition Wiley Eastern.
6. Rohatagi, V.K. and Saleh, A.K. Md . E. (2015), An Introduction to Probability and Statistics, 03^{rd} edition, Wiley.

IV. CORE COURSE [CCSTA324]
LINEAR MODELS & REGRESSION ANALYSIS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course objectives and outcomes:

1. Gain insights into transaction management and query processing techniques, facilitating effective data manipulation and retrieval within a database environment.
2. Comprehend the principles of regression analysis and the fundamental assumptions underlying it.
3. Utilize least squares estimation techniques to estimate regression coefficients effectively.
4. Evaluate the goodness-of-fit of regression models using appropriate metrics.
5. Identify and address specification errors in regression models through rigorous testing procedures.

Course Contents:

UNIT 1: Gauss-Markov linear Models, theory of linear estimation, Estimability of linear parametric functions, method of least squares, normal equations, Gauss-Markov theorem, Estimation of error variance. Distribution of quadratic forms.

UNIT 2: Simple linear regression model. Least-squares estimation of parameters. Hypothesis testing on the slope and intercept. Interval estimation in simple linear regression. Prediction of new observations. Coefficient of determination.

UNIT 3: Estimation by maximum likelihood. Multiple linear regression: Multiple linear regression models. Estimation of the model parameters. Hypothesis testing in multiple linear regression. Confidence intervals in multiple regression. Coefficient of determination and Adjusted R^2

UNIT 4: Checking of linearity between study and explanatory variable, Residual Analysis, Detection and treatment of outliers, Residual plots. The PRESS statistic. Outlier test based on Studentized Residual (Rstudent). Test for lack of fit of the regression model.

UNIT 5: Transformation and Weighting to Correct Model Inadequacies: Variance stabilizing transformations. Transformations to linearize the model. Analytical methods for selecting a transformation on study variable. Diagnostic for Leverage and Influence: Leverage, measures of influence. Polynomial Regression Models: Polynomial models in one variable. Computational techniques for variable selection. Logistic Regression: Introduction, Linear predictor and link functions, logit, probit, odds ratio, test of hypothesis.

Suggested Readings:

1. Bapat, R.B. (2012). Linear Algebra and Linear Models, 3rd Edition. Hindustan Book Agency.
2. Montegomery, D.C., Peck, E.A. & Vining, G.G. (2015). Introduction to Linear Regression Analysis, 5th Edition. Wiley.
3. Khuri, A.I. (2010). Linear Model Methodology. CRC Press. .
4. Rao, C.R. (2009). Linear Statistical Inference and its Applications, 2nd Edition. Wiley.
5. Draper, N.R. & Smith, H. (2011). Applied Regression Analysis, 3rd Edition. Wiley

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V. CORE COURSE [CCSTA325]
PRACTICAL

Marks: 100 (ESE Pr: 6 Hrs) = 100	Pass Marks = 45

(Credits: Theory-04, 60 Hours)

Practical Paper Syllabus: Linear Models & Regression Analysis

UNIT 1: Gauss-Markov Linear Models

Construction of design matrices and parametric functions. Verification of estimability of linear parametric functions. Solving normal equations using least squares method. Application of Gauss-Markov theorem to show BLUE property. Estimation of error variance. Distribution of quadratic forms with real datasets.

- **Exercises/Problems:**
    - Compute least squares estimates from given data.
    - Test estimability of functions like aμ+bτia\mu + b\tau_iaμ+bτi.
    - Illustrate distribution of quadratic forms.
- **Software Practice:** Manual solution + R/Python for matrix computation.

UNIT 2: Simple Linear Regression

Fitting a simple linear regression line. Estimation of regression coefficients (slope & intercept). Testing hypotheses on slope and intercept. Interval estimation of regression coefficients. Prediction of new observations with confidence limits. Calculation and interpretation of R2R^2R2 (Coefficient of Determination).

- **Exercises/Problems:**
    - Fit regression models to real-life data (height–weight, sales–advertising).
    - Compute and interpret regression diagnostics.
- **Software Practice:** Regression in R/SPSS/Excel with plots.

UNIT 3: Multiple Linear Regression & MLE

Maximum Likelihood Estimation (MLE) of regression parameters. Estimation of coefficients in multiple linear regression models. Hypothesis testing of regression coefficients. Confidence intervals for regression coefficients.

- **Exercises/Problems:**
    - Fit multiple regression models (e.g., predicting marks using hours studied, attendance, intelligence score).
- **Software Practice:** MLR in R/Python/SPSS, with interpretation of outputs.

UNIT 4: Model Checking & Diagnostics

Residual analysis: plotting and interpretation. Detection and treatment of outliers. Use of Studentized Residuals for outlier testing. PRESS statistic calculation and interpretation. Test for lack of fit of regression models.

- **Exercises/Problems:**
    - Perform residual analysis for given data sets.
    - Identify influential outliers using diagnostics.
    - Conduct lack-of-fit tests and interpret results.
- **Software Practice:** Generating diagnostic plots and outlier analysis in R.

UNIT 5: Advanced Regression Topics

(A) Transformations & Weighting

Applying variance-stabilizing transformations (log, square-root, Box–Cox). Transformations to linearize models. Weighted least squares estimation.

(B) Leverage & Influence

Computation of leverage (hat matrix). Cook's distance, DFFITS, and DFBETAS for influence detection.

(C) Polynomial Regression

Fitting polynomial regression models in one variable. Selecting optimal degree using model selection criteria.

(D) Logistic Regression

Fitting logistic regression models. Interpretation of coefficients in terms of odds ratio. Testing hypotheses in logistic regression. Prediction of classification probabilities.

- **Exercises/Problems:**
    - Apply Box–Cox transformation to correct non-normality.
    - Identify high-leverage points in a dataset.

  - Fit polynomial regression to growth data.
  - Fit logistic regression to binary outcome data (e.g., disease/no disease vs. age, smoking).
- **Software Practice:** R/Python/SPSS implementations of transformations, diagnostics, and logistic regression.

Suggested Readings:

1. Bapat, R.B. (2012). Linear Algebra and Linear Models, 3rd Edition. Hindustan Book Agency.
2. Montegomery, D.C., Peck, E.A. & Vining, G.G. (2015). Introduction to Linear Regression Analysis, 5th Edition. Wiley.
3. Khuri, A.I. (2010). Linear Model Methodology. CRC Press. .
4. Rao, C.R. (2009). Linear Statistical Inference and its Applications, 2nd Edition. Wiley.
5. Draper, N.R. & Smith, H. (2011). Applied Regression Analysis, 3rd Edition. Wiley

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SEMESTER IV

I. ELECTIVE COURSE-1A [ECSTA401A]
MACHINE LEARNING USING PYTHON

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives & Learning outcomes:

1. Understand how machine learning works and how to use Python for it.
2. Practice using different machine learning methods like supervised and unsupervised learning.
3. organize and clean data for machine learning tasks.
4. Choose the right machine learning method for different situations and evaluate how well it works.
5. Use Python libraries to build machine learning models.
6. Use machine learning to solve problems in areas like finance, healthcare, and marketing.

Course Contents:

UNIT 1: Basics of Python

Introduction to Python programming environment. Types of variables and standard data types (numeric, string, boolean). Lists, tuples, dictionaries, and sets with practical operations. Control statements (if–else, loops, iterations). Defining and using functions, scope of variables. Object-oriented programming: classes and objects. File handling: reading, writing, and managing files. Exception handling and debugging techniques.

UNIT 2: Essential Python Modules

Jupyter Notebook: interactive coding, markdown, visualization. NumPy: arrays, vectorized operations, matrix manipulation. SciPy: scientific computing, optimization, integration, statistics. Matplotlib: creating plots, charts, and visualizations. Pandas: data manipulation, indexing, cleaning, and summarization. mglearn: utilities and datasets for machine learning practice.

UNIT 3: Supervised Learning

Introduction to supervised learning: classification vs. regression. k-Nearest Neighbors (k-NN): distance-based classification and regression. Decision Trees: tree construction, splitting criteria, pruning, and interpretation. Neural Networks: perceptrons, multi-layer networks, training, and applications. Evaluation metrics for supervised learning models.

UNIT 4: Unsupervised Learning – I

Data preprocessing and normalization techniques. Feature scaling: standardization, min–max scaling, robust scaling. Dimensionality reduction: Principal Component Analysis (PCA). Feature extraction and selection methods. Manifold learning: t-SNE, Isomap, and related techniques for high-dimensional data.

UNIT 5: Unsupervised Learning – II

Introduction to clustering methods and applications. k-Means Clustering: centroid-based clustering and evaluation. Agglomerative Clustering: hierarchical clustering methods and dendrograms. DBSCAN: density-based clustering and noise handling. Comparison of clustering methods and use cases.

Suggested Readings:

1. Haslwanter, T. (2016): An Introduction to Statistics with Python: with Applications in the Life Sciences, Springer.
2. Sheppard, K. (2018): Introduction to Python for Econometrics, Statistics and Data analysis Oxford University press

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OR ELECTIVE COURSE-1B [ECSTA401B]
FINANCIAL STATISTICS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course objectives & Learning Outcomes

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

Course Contents:

UNIT 1: 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 2: Review and Extensions- Stochastic Calculus, Stochastic Differential Equations, Partial Differential Equations, Black- Scholes' PDE,

UNIT 3: Martingales and their Applications in Pricing of Assets, Plain Vanilla Options, Greeks of Plain Vanilla Options, Estimation of Volatility, CRR Model

UNIT 4: 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 5: 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.

OR ELECTIVE COURSE-1C [ECSTA401C]

APPLIED STOCHASTIC PROCESSES

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course objectives & 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.

Course Contents:

UNIT 1: Discrete Time Markov Chain: Deterministic and Stochastic approach to SIS Epidemic Model, Chain Binomial Greenwood and Reed-Frost Models. Determination of size and Duration.

UNIT 2: Review of Mathematical expectation, Generating Functions, Central Limit Theorem. Poisson Process: Generator Matrix, Kolmogorov Differential Equations, Stationary Probability Distribution.

UNIT 3: General Birth and Death Process, Simple Birth and Simple Death with Immigration, Population Extinction, First Passage Times, Logistic Growth Processes.

UNIT 4: 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 5: 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.

II. ELECTIVE COURSE-2A [ECSTA402A]
ADVANCED STATISTICAL COMPUTING & DATA MINING

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course objectives & Learning Outcomes:

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.

Course Contents:

UNIT 1: Random number generation: Review; simulating multivariate distributions; Simulating stochastic processes. Stochastic differential equations: introduction, Numerical solutions. Monte Carlo Integration; Variance reduction methods.

UNIT 2: Markov Chain Monte Carlo methods: The Metropolis–Hastings Algorithm; Gibbs sampling. EM algorithm. Smoothing with kernels: density estimation, choice of kernels.

UNIT 3: 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 4: Artificial neural networks: Introduction, multilayer perceptron network, selforganizing feature map and radial basis function network.

UNIT 5: 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:
4. Data Mining, Inference and Prediction, 2nd ed., Springer.
5. Han, J. and Kamber, M. (2000). Data Mining: Concepts and Techniques, Morgan Kaufmann.

OR ELECTIVE COURSE-2B [ECSTA402B]

ECONOMETRICS & TIME SERIES ANALYSIS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	**Pass Marks: (MSE: 17 + ESE: 28) = 45**

(Credits: Theory-04, 60 Hours)

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.

Course Contents:

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

UNIT 2: 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 3: 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, kclass estimators, Three Stage Least Squares (3SLS) and Full Information Maximum- Likelihood (FIML).

UNIT 4: Time series as discrete parameter stochastic process. Auto-covariance and Autocorrelation 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.

UNIT 5: 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.

OR ELECTIVE COURSE-2C [ECSTA402C]

ACTUARIAL STATISTICS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives& learning outcomes

1. Understand the principles of probability theory and its applications in actuarial science.
2. Gain proficiency in statistical modeling techniques relevant to insurance and risk management, such as survival analysis and credibility theory.
3. Apply statistical methods to analyze and interpret data sets related to mortality, morbidity, and other actuarial factors.
4. Develop skills in assessing and quantifying financial risks associated with insurance products and pension plans

Course Contents:

Unit 1: 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. Multiple life functions, joint life and last survivor status. .

Unit 2: Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement. Distribution of aggregate claims, compound Poisson distribution and its applications. Claim Amount distributions, approximating the individual model, Stop-loss insurance.

Unit 3: Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor

Unit 4: Life insurance: 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: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, varying annuities

UNIT 5: Net premiums: Continuous and discrete premiums, true monthly payment premiums. Net premium reserves: Continuous and discrete net premium reserves, reserves on a semi continuous basis, reserves based on true monthly

References:

1. Tse, Y. K. and Chan, W. S (2017): Financial Mathematics For Actuaries, World Scientific.
2. Medina, P.K. and Merino, S. (2003): A discrete introduction: Mathematical finance and Probability,Birkhauser.
3. Vecer, J. (2017): Stochastic Finance: A Numeric Approach, CRC Press.
4. Perna, C. and Sibillo, M. (2016): Mathematical and Statistical Methods for Actuarial Sciences And Finance, Springer

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III. CORE COURSE [CCSTA403]
ORDER STATISTICS

Marks: 30 (MSE: 20 Th. 1Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE :28) = 45

(Credits: Theory-04, 60 Hours)

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. Learn about the joint and marginal distributions of order statistics from a sample containing a single outlier.
9. Learn about the two candidates Ballot Box problem, its extension, generalization and application to fluctuations of sums of random variables.
10. Learn about the basic concepts of record values and generalized order statistics.

Course Contents:

UNIT 1: 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 2: 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 3: 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 4: Order statistics for independently and not identically distributed (i.i.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.

UNIT 5: 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
4. Statistics, Atlantis Studies in Probability and Statistics, Vol. III. Atlantis Press.
5. David, H. A. and Nagaraja, H. N. (2003). Order Statistics, 3rd ed., John Wiley & Sons.
6. Gibbons, J.D. and Chakraborti, S. (1992). Nonparametric Statistical Inference, 3rd ed., Marcel Dekker.
7. Shahbaz, M. Q., Ahsanullah, M., Shahbaz, S. H. and Al-Zahrani, B. M. (2016). Ordered Random variables: Theory and Applications. Springer.

IV. ELECTIVE COURSE-4A [EPSTA404A]
PRACTICAL-A

Marks: 100 (ESE Pr: 6 Hrs) = 100	Pass Marks = 45

(Credits: Practical-04, 120Hours)

Instruction to Question Setter for
End Semester Examination (ESE Pr):
There will be one Practical Examination of 3Hrs duration. Evaluation of Practical Examination may be as per the following guidelines:

Experiment/Lab work	*= 70 marks*
Practical record notebook	*= 05 marks*
Attendance	*= 05 marks*
Viva-voce	*= 20 marks*

Practical Paper Syllabus

UNIT 1: Python Fundamentals & Random Number Simulation

Writing basic Python programs using variables, lists, dictionaries, and loops. Functions and classes for modular programming. File handling and exception management. Random number generation with NumPy and Python's random module. Simulation of univariate and multivariate distributions. Simulating simple stochastic processes (Poisson, Markov chains, Brownian motion). Numerical solutions of stochastic differential equations (Euler–Maruyama method). Monte Carlo integration and variance reduction techniques (antithetic, control variates).

- **Exercises:**
    - Generate samples from Normal, Binomial, and Poisson distributions.
    - Simulate Brownian motion paths.
    - Estimate integrals using Monte Carlo and compare with exact results.

UNIT 2: Monte Carlo & Kernel Methods

Implementing Metropolis–Hastings algorithm for given distributions. Gibbs sampling for multivariate distributions. EM algorithm for parameter estimation (e.g., Gaussian Mixture Models). Kernel density estimation: Gaussian kernel, Epanechnikov kernel. Practical selection of bandwidth in density estimation.

- **Exercises:**
    - Use MCMC to approximate expectations under complex distributions.
    - Apply EM algorithm to estimate parameters in a two-component Gaussian mixture.
    - Perform kernel density estimation and visualize results.

UNIT 3: Classical & Modern Machine Learning Approaches

Review of multivariate classification methods (e.g., LDA, QDA). Implementation of classification and regression trees (CART). Clustering approaches: k-means, hierarchical clustering, DBSCAN. Data mining viewpoint: vector quantization and k-means extensions. Practical applications in supervised vs. unsupervised learning.

- **Exercises:**
    - Classify datasets using decision trees and compare with LDA/QDA.
    - Perform k-means clustering on a real dataset (e.g., Iris, MNIST subsets).
    - Compare clustering results from statistical vs. data mining methods.

UNIT 4: Artificial Neural Networks

Implementation of perceptron learning algorithm. Training multilayer perceptrons (MLPs) using backpropagation.
Visualization of decision boundaries learned by ANNs. Self-Organizing Feature Maps (SOMs): clustering and visualization. Radial Basis Function (RBF) networks for function approximation.

- **Exercises:**
    - Build and train a neural network for binary classification.
    - Train an MLP to approximate a non-linear regression function.
    - Implement a SOM for visualization of high-dimensional data.

UNIT 5: Advanced Models & Applications

Concept of structural risk minimization. Support Vector Machines (SVM): linear, polynomial, and RBF kernels. Comparison of SVMs with logistic regression and decision trees. Case studies and applications in finance, health, and image recognition. Overview of current applications of machine learning and deep learning.

- **Exercises:**
    - Train and test SVMs on classification datasets.
    - Compare model performance using accuracy, precision, recall, and ROC curves.
    - Apply SVMs to real-world datasets (text classification, image data).

Note:

1. MS Excel/ SPSS/R/ PYTHON or Any Statistical Software and Computer System may be provided by the Institution.
2. However, Use of Smartphone or Web is restricted in the Examination.

OR ELECTIVE COURSE-4B [EPSTA404B]

PRACTICAL-B

Marks: 100 (ESE Pr: 6 Hrs) = 100	**Pass Marks = 45**

(Credits: Theory-04, 60 Hours)

Instruction to Question Setter for

<u>End Semester Examination (ESE Pr):</u>

There will be one Practical Examination of 3Hrs duration. Evaluation of Practical Examination may be as per the following guidelines:

Experiment/Lab work	*= 70 marks*
Practical record notebook	*= 05 marks*
Attendance	*= 05 marks*
Viva-voce	*= 20 marks*

Practical Paper Syllabus: Financial Mathematics, Econometrics & Time Series

UNIT 1: Asset Pricing & Stochastic Processes

Simulation of random walks and geometric Brownian motion. Generating and analyzing Wiener processes using Python/R. Pricing of basic derivative instruments in discrete and continuous time models. Hedging strategies and computation of Greeks (Delta, Gamma, Theta, Vega, Rho).

- **Exercises:**
  - Simulate stock price paths under GBM.
  - Estimate option prices using Monte Carlo methods.
  - Compute Greeks numerically for plain vanilla options.

UNIT 2: Stochastic Calculus & Black–Scholes Models

Solving stochastic differential equations (Euler–Maruyama and Milstein schemes). Application of Ito's Lemma in pricing. Derivation and implementation of Black–Scholes PDE. Numerical methods for solving PDEs in finance.

- **Exercises:**
  - Solve SDEs for asset price dynamics.
  - Implement Black–Scholes model and verify theoretical option prices.
  - Compare simulation results with closed-form solutions.

UNIT 3: Martingales & Option Pricing

Simulation and verification of martingale properties. Pricing of plain vanilla options using CRR binomial tree model. Estimation of volatility from historical data (real dataset). Greeks of plain vanilla options: computation and interpretation.

- **Exercises:**
  - Implement CRR model for option pricing.
  - Estimate volatility using moving window techniques.
  - Backtest option pricing models with market data.

UNIT 4: Advanced Financial Instruments

Pricing of exotic options (Asian, Exchange, Barrier). Reflection principle and application to exotic derivatives. Forward rate modeling (Vasicek model) and interest rate derivatives pricing. Default risk modeling in bond markets, Credit Default Swaps pricing.

- **Exercises:**
  - Price Asian and Barrier options using Monte Carlo simulation.
  - Implement Vasicek model for forward rates.
  - Simulate credit risk and CDS spread estimation.

UNIT 5: Jump Processes in Finance

Simulation of Poisson and compound Poisson processes. Ito calculus with jumps and SDEs with jumps. Levy processes and Girsanov transformation with jumps. Pricing and hedging using jump-diffusion models. Black–Scholes PDE with jumps.

Exercises:
  - Simulate jump-diffusion asset paths.
  - Price European options under Merton's jump-diffusion model.

- Compare risk-neutral pricing under diffusion vs. jump models.

UNIT 6: Econometric Methods – Linear Models

Implementation of GLM and GLS estimators. Instrumental Variable (IV) estimation in presence of endogeneity. Bayesian estimation of regression models using priors (conjugate & non-informative). Hypothesis testing on regression coefficients under Bayesian framework.

- **Exercises:**
  - Apply GLS on heteroscedastic regression data.
  - Estimate regression coefficients using IV method.
  - Conduct Bayesian analysis of linear models in R/Python (PyMC/Stan).

UNIT 7: Dynamic Econometric Models

Estimation of distributed lag and polynomial lag models. Almon lag estimation and determination of optimal lag length. Adaptive expectation and partial adjustment models. Estimation of Vector Auto Regression (VAR). Conducting Granger causality test.

- **Exercises:**
  - Fit distributed lag model to macroeconomic data.
  - Implement Almon lag polynomial fitting.
  - Estimate VAR model and perform Granger causality test.

UNIT 8: Simultaneous Equation Models

Identification: order and rank condition checks. Recursive and non-recursive system estimation. Two Stage Least Squares (2SLS), Limited Information and k-class estimators. Three Stage Least Squares (3SLS) and Full Information ML (FIML).

- **Exercises:**
  - Check identification for structural equations.
  - Estimate simultaneous equation models using 2SLS and 3SLS.
  - Compare efficiency of different estimators.

UNIT 9: Time Series Modeling

Simulation of stationary processes (AR, MA, ARMA). Fitting ARIMA and SARIMA models to real datasets (finance, economics). Box–Jenkins methodology for model identification, estimation, and diagnostics. Forecasting using ARIMA models.

- **Exercises:**
  - Simulate AR(1) and MA(1) processes and estimate parameters.
  - Fit ARIMA models to financial/economic data.
  - Perform residual diagnostics and forecast future values.

UNIT 10: Spectral Analysis & Forecasting

Estimation of autocovariance and autocorrelation functions. Construction of correlogram and periodogram. Spectral representation and smoothing of spectral density. Forecasting using exponential smoothing methods (simple, Holt's, adaptive).

- **Exercises:**
  - Estimate and plot ACF and PACF for given time series.
  - Construct periodograms and estimate spectral densities.
  - Apply exponential smoothing to forecast economic/financial data.

Note:

1. MS Excel/R/PYTHON/SPSS or Any Statistical Software and Computer System may be provided by the Institution.
2. However, Use of Smartphone or Web is restricted in the Examination.

OR ELECTIVE COURSE-4C [EPSTA404C]
PRACTICAL-C

Marks: 100 (ESE Pr: 6 Hrs) = 100	Pass Marks = 45

(Credits: Theory-04, 60 Hours)

Instruction to Question Setter for
End Semester Examination (ESE Pr):
There will be one Practical Examination of 3Hrs duration. Evaluation of Practical Examination may be as per the following guidelines:
Experiment/Lab work = 70 marks
Practical record notebook = 05 marks
Attendance = 05 marks
Viva-voce = 20 marks

Practical Paper Syllabus: Stochastic Processes, Epidemic Models, and Actuarial Mathematics

PART A: Stochastic Processes & Epidemic Models

UNIT 1: Discrete Time Markov Chains & Epidemic Models
Simulation of SIS epidemic model using deterministic and stochastic approaches. Chain-binomial models: Greenwood and Reed–Frost models. Estimation of epidemic size and duration from simulated data.

- **Exercises:**
  - Implement Reed–Frost model for a small population.
  - Compare deterministic vs stochastic SIS epidemic outcomes.
  - Estimate expected epidemic duration under varying infection probabilities.

UNIT 2: Poisson Process & Expectation Theory
Simulation of Poisson arrivals and inter-arrival times. Use of generating functions in probability distributions. Verification of Central Limit Theorem using simulations. Estimation of stationary distributions for continuous-time Markov chains.

- **Exercises:**
  - Simulate Poisson process and compute mean/variance.
  - Verify CLT with simulated data.
  - Solve Kolmogorov forward and backward equations numerically.

UNIT 3: Birth and Death Processes
Simulation of general birth-death processes. Population extinction probabilities and expected times. First passage time distributions. Logistic growth simulation with stochastic effects.

- **Exercises:**
  - Simulate simple birth, simple death, and immigration models.
  - Estimate extinction probability for small populations.
  - Study first passage time to threshold in a birth-death model.

UNIT 4: Continuous-Time Markov Chains in Biological Systems
Simulation of SIR epidemic model (deterministic vs stochastic). Competition process modeling. Predator-prey dynamics using stochastic simulations.

- **Exercises:**
  - Compare deterministic vs stochastic SIR models.
  - Simulate predator-prey dynamics with random fluctuations.
  - Estimate epidemic size distribution via Monte Carlo simulations.

UNIT 5: Diffusion Processes & Stochastic Differential Equations (SDEs)
Simulation of Brownian motion and Ornstein–Uhlenbeck process. Numerical solutions to SDEs (Euler–Maruyama, Milstein methods). Application of SDEs in population and epidemic models.

- **Exercises:**
  - Simulate diffusion approximations to epidemic models.
  - Apply SDEs to logistic growth with noise.
  - Compare discrete epidemic models with their diffusion approximations.

PART B: Actuarial Mathematics & Insurance Models

UNIT 1: Survival Models & Life Tables
Calculation of survival functions and forces of mortality. Construction of life tables from sample survival data. Joint life and last survivor probabilities.

- **Exercises:**
  - Estimate survival function from real/simulated lifetime data.
  - Construct a curtate future lifetime distribution.
  - Simulate joint life survival probabilities.

UNIT 2: Multiple Decrement & Claim Models
Construction of multiple decrement tables. Simulation of deterministic vs random survivorship groups. Distribution of aggregate claims under compound Poisson model.

- **Exercises:**
  - Construct decrement tables for 2–3 causes of exit.
  - Simulate aggregate claims using Poisson–Exponential and Poisson–Gamma models.
  - Estimate stop-loss insurance premiums.

UNIT 3: Interest Theory & Accumulation
Computation of nominal vs effective interest rates. Calculation of accumulation factors, present value, and force of interest.

- **Exercises:**
  - Compare accumulation using nominal vs effective interest rates.
  - Compute present value of varying cashflows.
  - Estimate force of mortality-adjusted accumulation.

UNIT 4: Life Insurance & Annuities
Premium calculation for various life insurance products: whole life, endowment, deferred. Simulation of continuous, discrete, and varying life annuities.

- **Exercises:**
  - Compute actuarial present value for level and varying benefit insurances.
  - Evaluate present values of annuities with monthly and yearly payments.
  - Compare deterministic vs stochastic mortality assumptions.

UNIT 5: Premiums & Reserves
Calculation of net premiums (continuous, discrete, monthly). Reserve calculations using various approaches (continuous, semi-continuous, true monthly).

- **Exercises:**
  - Compute premiums for different life insurance contracts.
  - Calculate net premium reserves at different policy durations.
  - Implement recursive formula for reserve calculation.

Software Tools: R, Python, MATLAB, or Excel (with actuarial add-ins).

Note:
1. MS Excel/SPSS/R/ PYTHON or Any Statistical Software and Computer System may be provided by the Institution.
2. However, Use of Smartphone or Web is restricted in the Examination.

V. PROJECT [PRSTA425]
DISSERTATION/ PROJECT/ TEACHING APTITUDE

Marks: 100 (ESE Pr: 6 Hrs) = 100	Pass Marks = 45

(Credits: Theory-04, 120 Hours)

Guidelines to Examiners for End Semester Examination (ESE):
Evaluation of project dissertation work may be as per the following guidelines:
Project model (if any) and the Project record notebook = 70 marks
Project presentation and viva-voce = 30 marks

The evaluation of the dissertation will be done in 100 marks (70 marks + 30 marks of the session). The sessional component will be evaluated by the concerned supervisor.

The end term evaluation (70 marks) will be done by a board of examiners. The end term evaluation in 70 marks will include the literary and scientific presentation of the dissertation and the performance in the viva-voce.

The overall project dissertation may be evaluated under the following heads:
- *Motivation for the choice of topic*
- *Project dissertation design*
- *Methodology and Content depth*
- *Results and Discussion*
- *Future Scope & References*
- *Participation in an Internship programme with a reputed organisation*
- *Application of Research techniques in Data collection*
- *Report Presentation*
- *Presentation style*
- *Viva-voce*

Course Objectives:
1. To develop research skills and scientific inquiry through independent investigations on a topic/ problem.

Course Outcomes:
On successful completion of this course, the student should know:
1. About conducting research with approved stages of research methodology.
2. A dissertation will enable students to further investigate and navigate different aspects and events of life through research.

PROJECT WORK
Each student has to submit three copies of hard-bound dissertation work (along with the raw data), duly forwarded by the HOD of the Department concerned. The forwarded copies will be submitted to the concerned University Department, Ranchi University, Ranchi for evaluation (one month before the viva voce examination).

The paper may involve:
a) Field work/ Lab work related to the project.
b) Survey research, Case Study or any other type of research related to the subject.
c) One Large study/ Experiment or several studies/ Experiments, depending on the objectives of the research.
d) The writing of the dissertation must be within 80 to 100 pages, including references and appendices.
e) Content must be typed in Font: Times New Roman with Line Spacing: 2.0 and Font Size 12 points.

The project work will be presented in a seminar on the assigned topic in the concerned department of Ranchi University, Ranchi, followed by an open viva voce examination.

Topics: As decided by the Supervisor/Guide

Teaching Aptitude: As an alternative to a dissertation, only a few selected meritorious candidates may be assigned the responsibility to teach the pre-decided topics in selected colleges. The performance may be evaluated based on the structured feedback for the candidate.
