SISTER NIVEDITA UNIVERSITY

SCHOOL OF SCIENCES

DEPARTMENT OF STATISTICS

COURSE STRUCTURE AND SYLLABUS OF B.SC. (HONS.) STATISTICS PROGRAMME

ACADEMIC YEAR 2023-2024

Framed according to the National Education Policy (NEP 2020)

SISTER NIVEDITA UNIVERSITY

SCHOOL OF SCIENCES

DEPARTMENT OF STATISTICS

VISION OF THE DEPARTMENT

The department of Statistics aspires to establish and develop a nucleus of academic eminence and calibre in mathematical and applied Statistics through dynamic teaching, learning and collaborative research work thereby bringing out the best statisticians.

MISSION STATEMENT OF THE DEPARTMENT

Our mission is to perpetuate a department that is reckoned as equal to any in terms of its relevance of teaching and research, its quality of support, facilities, the learning opportunities and the working experience it offers.

SISTER NIVEDITA UNIVERSITY

SCHOOL OF SCIENCES

DEPARTMENT OF STATISTICS

Program Name: B.SC. (HONS.) STATISTICS

PROGRAMME EDUCATIONAL OBJECTIVES (PEO)

PEO 01: Graduates will serve effectively in industry, society and competent to pursue their higher studies.

PEO 02: Graduates will have the knowledge of C++ and R language which will be very useful in Data Analytics, Pharmaceutical and various other corporate fields.

PEO 03: Graduates will develop the mentality to continuously adapt their mindset to change according to the needs, like they can learn new things, new programming languages like Python, SAS, Geneva etc. and engage in lifelong learning.

PEO 04: Graduates will develop the communicating skills both in verbal and written to communicate the whole world and learn the ethics which they will apply in later life.

SISTER NIVEDITA UNIVERSITY

SCHOOL OF SCIENCES

DEPARTMENT OF STATISTICS

Program Name: B.SC. (HONS.) STATISTICS

PROGRAMME OUTCOMES (PO)

PO 01: Statistical Knowledge: Apply the knowledge of statistical and mathematical fundamentals and a statistical specialization to the solution of advanced statistical problems.

PO 02: Design/development of solutions: Design solutions for statistical problems and design system or processes that meet the specified needs with appropriate consideration for the application of statistical tools.

PO 03: Modern tool usage: Create, select and apply appropriate techniques, resources and tools including prediction and modelling.

PO 04: Problem Solving: The students will be able to critically examine various hypotheses and research queries, and will be able to identify and consult relevant resources to find their rational answers.

PO 05: The Statistician and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant in the field of Statistics.

SISTER NIVEDITA UNIVERSITY

SCHOOL OF SCIENCES

DEPARTMENT OF STATISTICS

Program Name: B.SC. (HONS.) STATISTICS

PROGRAMME OUTCOMES (PO)

PO 06: Environment and sustainability: Understand the impact of the statistical knowledge in findings the solutions in societal and environmental contexts and demonstrate the knowledge of and need for sustainable development.

PO 07: Ethics: Apply ethical principles and able to identify ethical issues avoid unethical behaviour such as fabrication, falsification or misrepresentation and misinterpretation of data.

PO 08: Individual and team work: Function effectively as an individual and as a member or leader in diverse teams and in multidisciplinary settings.

PO 09: Communication: Communicate effectively with all statistics related activities with the community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 10: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of social and technological change.

SISTER NIVEDITA UNIVERSITY

SCHOOL OF SCIENCES

DEPARTMENT OF STATISTICS

Program Name: B.SC. (HONS.) STATISTICS

PROGRAMME SPECIFIC OUTCOMES (PSO)

PSO 01: Student is equipped with statistical modeling, ability, problem solving skills, creative talent and power of communication necessary for various kinds of employment.

PSO 02: Gather core knowledge of the elementary concepts of statistics which include the vast areas of probability theory, probability distributions, sampling distributions, statistical inference, survey sampling, time series analysis, design of experiments, statistical quality control, multivariate analysis and many more.

PSO 03: Student should be able to apply their knowledge and skills that are transform the information presented verbally into statistical form, choose suitable statistical tools and techniques in order to process the information and make relevant decisions.

PSO 04: Students should be able to enhance their theoretical and technical skills to compete in both national and international level to pursue a promising career in both government and private sectors.

SISTER NIVEDITA UNIVERSITY

Undergraduate course structure for Statistics

As per NEP 2020 regulation and according to UGC-CBCS

Course Structure for

B.Sc. in Statistics

And

B.Sc. (Hons.) in Statistics / B.Sc. (Hons. with Research) in Statistics

Category definition with credit breakup

Semester	Credits									Credits/ Semester
	MC	NON MAJOR		MDC	AEC	SEC	VAC	INT	Project	
		NM	NV							
I	8	4	1+1	-	2	3	2	-	-	21
II	8	-	1+1	3	2	3	2	-	-	20
III	9	4	1+1	3	2	-	-	-	-	20
IV	9	4	1+1	3	2	-	-	-	-	20
V	13	-	1+1	-	-	3	2	-	-	20
VI	12	4	1+1	-	-	-	-	3	-	21
VII	12	4		-	-	-	-	-	4	20
VIII	12 / 16	-	-	-	-	-	-	-	8 / 4	20
Credits / Course	83/ 87	32		9	8	9	6	3	12 / 8	-
Total Credit										162

MC – Major Courses, NM – Non Major Minor, NV – Non Major Vocational, MDC – Multidisciplinary Courses, AEC – Ability Enhancement Courses, SEC – Skill Enhancement Courses, VAC – Value Added Courses, INT – Internship, Project – Dissertation/Project.

Semester I:

Category	Course Name	Credit	Teaching Scheme		
			L	T	P
Semester I					
MC1	Descriptive Statistics I	3	3	0	0
	Descriptive Statistics I LAB	1	0	0	2
MC2	Probability I	4	4	0	0
NM1	Real Analysis	4	4	0	0
NV1	Vocational – EAA I (Yoga/ Sports/ NCC/ NSS)	1	0	0	2
NV2	Vocational – Soft Skill Development I	1	1	0	0
AEC1	Communicative English I	2	2	0	0
VAC1	Environmental Science I	2	2	0	0
SEC1	Computer Application	3	3	0	0
Total Credit = 21			**Teaching Hour = 23**		

Semester II:

Category	Course Name	Credit	Teaching Scheme		
			L	T	P
Semester II					
MC3	Linear Algebra	3	3	0	0
	Linear Algebra LAB	1	0	0	2
MC4	Probability II	3	3	0	0
	Probability II LAB	1	0	0	2
NV3	Vocational – EAA I (Yoga/ Sports/ NCC/ NSS)	1	0	0	2
NV4	Vocational – Soft Skill Development II	1	1	0	0
MDC1	Selected by the candidate (Elective)	3	3	0	0
AEC2	Communicative English II	2	2	0	0
VAC2	Environmental Science II	2	2	0	0
SEC2	Basic Management Skill	3	3	0	0
Total Credit = 20			**Teaching Hour = 23**		

Semester III:

Category	Course Name	Credit	Teaching Scheme		
			L	T	P
Semester III					
MC5	Descriptive Statistics II	3	3	0	0
	Descriptive Statistics II LAB	1	0	0	2
MC6	Sampling Distributions	5	5	0	0
NM2	XXXXX	3	3	0	0
	XXXXX	1	0	0	2
NV5	Vocational – Mentored Seminar I	1	0	0	2
NV6	Vocational – Soft Skill Development III	1	1	0	0
MDC2	Selected by the candidate (Elective)	3	3	0	0
AEC3	Logical Ability I / Foreign Language I	2	2	0	0
Total Credit = 20			**Teaching Hour = 23**		

Semester IV:

Category	Course Name	Credit	Teaching Scheme		
			L	T	P
Semester IV					
MC7	Statistical Inference I	3	3	0	0
	Statistical Inference I LAB	1	0	0	2
MC8	Economic Statistics	4	4	0	0
	Economic Statistics LAB	1	0	0	2
NM3	XXXXX	3	3	0	0
	XXXXX	1	0	0	2
NV7	Vocational – Mentored Seminar I	1	0	0	2
NV8	Vocational – Soft Skill Development IV	1	1	0	0
MDC3	Selected by the candidate (Elective)	3	3	0	0
AEC4	Logical Ability II / Foreign Language II	2	2	0	0
Total Credit = 20			**Teaching Hour = 24**		

Semester V:

Category	Course Name	Credit	Teaching Scheme		
			L	T	P
Semester V					
MC9	Statistical Inference II	3	3	0	0
	Statistical Inference II LAB	1	0	0	2
MC10	Linear Models	3	3	0	0
	Linear Models LAB	1	0	0	2
MC11	Numerical Analysis Using C++	3	3	0	0
	Numerical Analysis Using C++ LAB	2	0	0	4
NV9	Vocational – Mentored Seminar I	1	0	0	2
NV10	Vocational – Soft Skill Development V	1	1	0	0
SEC3	Data Analysis	3	3	0	0
VAC3	Ethics Study and IPR	2	2	0	0
Total Credit = 20			**Teaching Hour = 25**		

Semester VI:

Category	Course Name	Credit	Teaching Scheme		
			L	T	P
Semester VI					
MC12	Design of Experiments	3	3	0	0
	Design of Experiments LAB	1	0	0	2
MC13	Survey Sampling	3	3	0	0
	Survey Sampling LAB	1	0	0	2
MC14	Statistical Computing Using R	3	3	0	0
	Statistical Computing Using R LAB	1	0	0	2
NM4	XXXXX	3	3	0	0
	XXXXX	1	0	0	2
NV11	Vocational – Mentored Seminar I	1	0	0	2
M14	Vocational – Soft Skill Development VI	1	1	0	0
INT1	Internship	3	0	0	6
Total Credit = 21			**Teaching Hour = 29**		

Semester VII:

Category	Course Name	Credit	Teaching Scheme		
			L	T	P
Semester VII					
MC15	Statistical Inference III	3	3	0	0
	Statistical Inference III LAB	1	0	0	2
MC16	Regression Analysis	3	3	0	0
	Regression Analysis LAB	1	0	0	2
MC17	Statistical Quality Control	3	3	0	0
	Statistical Quality Control LAB	1	0	0	2
Project	Dissertation / Minor Project	4	0	0	8
NM5	XXXXX	3	3	0	0
	XXXXX	1	0	0	2
Total Credit = 20			**Teaching Hour = 28**		

Semester VIII:

Category	Course Name	Credit	Teaching Scheme		
			L	T	P
Semester VIII					
MC18	Multivariate Analysis	3	3	0	0
	Multivariate Analysis LAB	1	0	0	2
MC19	Discrete Data Analysis	3	3	0	0
	Discrete Data Analysis LAB	1	0	0	2
MC20	Demography and Survival Analysis	3	3	0	0
	Demography and Survival Analysis LAB	1	0	0	2
Project/ Courses	Dissertation/(Operations Research+ Final Project / Seminar)	8/ (4+4)	0/ (3+0)	0	16/ (2+8)
Total Credit = 20			**Teaching Hour = 31 / 28**		

SISTER NIVEDITA UNIVERSITY

Undergraduate syllabus for Statistics

As per NEP 2020 regulation and according to UGC-CBCS

Syllabus for

B.Sc. in Statistics

And

B.Sc. (Hons.) in Statistics / B.Sc. (Hons. with Research) in Statistics

Semester I

1090010101	MC1 – Descriptive Statistics I	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	12^{th} level Mathematics				
Co-requisites	----				

Learning objectives:

- Learning basic statistical tools, types of qualitative and quantitative data, diagrammatic and graphical representation and organize, manage and present data.
- Acquire the knowledge about different measures of central tendency, dispersion, moments, skewness and kurtosis, bivariate data.

Course learning outcomes*:*

CO1: **Build** knowledge about basic statistical methods and representations of data.
CO2: **Explain** the concept of frequency distributions and their graphical representations.
CO3: **Make use of** the knowledge about the measures of central tendency.
CO4: **Make use of** the knowledge about the measures of absolute and relative dispersion.
CO5: **Make use of** the knowledge about the measures of moments, skewness and kurtosis.
CO6: **Apply** the concepts of scatter diagram, simple correlation, rank correlation, simple linear regression and curve fitting.

Course Content:

Unit I: Introduction to Statistical Methods **[10L]**

Definition and scope of Statistics, concepts of statistical Population and Sample. Data: Quantitative and Qualitative, Discrete and Continuous, Cross-sectional and Time-series, Primary and Secondary. Scales of measurement: Nominal, Ordinal, Interval and Ratio. Presentation of data: textual, tabular and graphical. Frequency distributions, cumulative frequency distributions and their graphical representations. Stem and Leaf displays.

Unit II: Univariate Data Analysis **[14L]**

Measures of Central Tendency: Mean, Median, Mode. Measures of Dispersion: Range, Mean deviation, Standard deviation, Quartile deviation, Coefficient of variation. Moments, Skewness and Kurtosis. Sheppard's corrections for Moments. Box Plot and Outliers detection.

Unit III: Bivariate Data Analysis **[12L]**

Definition, Scatter diagram, simple Correlation, simple linear Regression, principle of least squares, fitting of Polynomial and Exponential curves, Rank correlation: Spearman's and Kendall's measures (untied and tied cases).

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edition. The World Press, Kolkata.
2. Miller Irwin and Miller Marylees (2006): John E. Freund's Mathematical Statistics with Applications, 7th Edition., Pearson Education, Asia.
3. Mood A.M., Graybill F.A. and Boes D.C. (2007): Introduction to the Theory of Statistics, 3rd Edition. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.

1090010201	MC1 – Descriptive Statistics I LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Descriptive Statistics I Theory				
Co-requisites	Use of scientific calculators and/or Microsoft Excel				

Learning objectives:

To provide students the hands-on experience of different statistical methods relating the analysis of univariate and bivariate statistical data.

Course learning outcomes*:*

***CO1*: Understand** tabular and diagrammatic representations of frequency distribution of discrete and continuous data using scientific tools.
***CO2:* Solve** numerical problems based on the measures of central tendency.
***CO3:* Solve** numerical problems based on the measures of absolute and relative dispersion.
***CO4:* Solve** numerical problems based on moments, measures of skewness and kurtosis.
***CO5:* Apply** the knowledge of descriptive measures for simple correlation and rank correlation for solving its problems.
***CO6:* Apply** the knowledge of descriptive measures for simple regression for solving its problems.

Course Content:

List of experiments (to be executed using Scientific Calculators and/or MS Excel)

Sl. No.	Name of the Experiments
1	Graphical representation of data.
2	Problems based on construction of frequency distributions and their graphical representations, Stem and Leaf plot.
3	Problems based on measures of Central Tendency.
4	Problems based on measures of Dispersion.
5	Problems based on combined mean and variance and coefficient of variation.
6	Problems based on Moments, Skewness and Kurtosis.
7	Problems related to Quantiles and measures based on them, construction of Box and Whisker plot.
8	Problems based on analysis of Bivariate data.
9	Problems based on measures of Rank Correlation.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edition. The World Press, Kolkata.
2. Miller Irwin and Miller Marylees (2006): John E. Freund's Mathematical Statistics with Applications, 7th Edition., Pearson Education, Asia.

3. Mood A.M., Graybill F.A. and Boes D.C. (2007): Introduction to the Theory of Statistics, 3rd Edition. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.

1090010102	MC2 – Probability I	C	L	T	P
Version 1.0	**Contact Hours – 48**	4	4	0	0
Pre-requisites/Exposure	12^{th} level Mathematics				
Co-requisites	----				

Learning objectives:

- To develop the concepts of introductory Probability Theory, Conditional Probability, Bayes' theorem and their applications
- To provide students with an exposure to the fundamental concepts of one dimensional Random Variables and their related properties.
- To help students in forming the concepts of different Probability Inequalities and Generating Functions.

Course learning outcomes*:*

CO1: **Apply** the concepts of basic probability.
CO2: **Apply** the concepts of conditional probability, Bayes' theorem and independent events.
CO3: **Build** the fundamental knowledge of one dimensional discrete random variables and their related properties.
CO4: **Build** the fundamental knowledge of one dimensional continuous random variables and their related properties.
CO5: **Develop** the concepts of different probability inequalities along with their applications.
CO6: **Develop** the concepts of generating functions along with their applications.

Course Content:

Unit I: Introductory Probability **[16L]**

Introduction, Random Experiments, Sample Space, concept of three types of Sample Spaces – finite, countably infinite and uncountably infinite, Events and Algebra of Events, Definitions of Probability – Classical, Statistical and Axiomatic, applications.

Unit II: Conditional Probability **[8L]**

Conditional Probability, laws of Addition and Multiplication, theorem of Total Probability, Bayes' theorem and its applications, Independent events.

Unit III: Random Variables **[16L]**

Definition, probability distribution of Random Variables, Cumulative Distribution Function (C.D.F.) and its properties (with proof), Discrete and Continuous Random Variables, Probability Mass Function (P.M.F.) and Probability Density Function (P.D.F.), Expectation and Moments, Dispersion, Skewness, Kurtosis, Quantiles.

Unit IV: Probability Inequalities and Generating Functions **[8L]**

Probability inequalities (Markov's and Chebychev's). Generating Functions, Probability Generating Function (P.G.F.), Moment Generating Function (M.G.F.), Uniqueness and inversion theorems (without proof) along with applications.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edition. World Press, Kolkata.
2. Gun A.M., Gupta M.K. & Dasgupta, B. (1994): An Outline of Statistical Theory, Vol. I, World Press.
3. Gun A.M. and Roy D. (2006): Problems In Probability Theory, 2nd Edition, World Press.
4. Ross S. (2002): A First Course in Probability, Prentice Hall.
5. Feller W. (1968): An Introduction to Probability Theory & its Applications, John Wiley.
6. Uspensky J.V. (1937): Introduction to Mathematical Probability, McGraw Hill.

Semester II

1090011103	MC3 – Linear Algebra	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	12^{th} level Mathematics				
Co-requisites	----				

Learning objectives:

Learning Linear Algebra is a necessity in any modern scientific experiment. It has a huge application in analytic geometry, engineering, physics, natural sciences, computer science, computer animation and the social sciences (specially in economics). Main objectives of this course are:

- To develop the concepts of vectors, vector spaces and its subspaces. To provide students with an exposure to the fundamental concepts of matrices and their related properties.
- To help students in forming the concepts of system of linear equations and different quadratic forms.

Course learning outcomes*:*

CO1: **Apply** the concepts of vectors in various field of experiments.
CO2: **Apply** the concepts of matrices to solve modern scientific problems.
CO3: **Build** the fundamental knowledge of determinants.
CO4: **Understand** the different applications of system of linear equations.
CO5: **Develop** the concepts of eigen values and eigen vectors.
CO6: **Make use of** the knowledge of quadratic forms.

Course Content:

Unit I: Vectors and Vector Spaces **[12L]**

Definition of vectors, operation of vectors, norm of a vector, distance and angle between two vectors. Vector spaces, subspaces, direct sum of subspaces, Span of a set of vectors, linear dependence and independence, spanning set, basis and its dimension. Replacement theorem, Dimension theorem, Extension and Contraction of a basis. Orthogonal vectors, Gram-Schmidt Orthogonalization Technique. Orthogonal and Orthonormal bases. Ortho-complement subspaces.

Unit II: Matrices **[8L]**

Definition of matrix. Algebra of matrices, basic elementary operations of rows and columns of a matrix. Elementary matrices and their uses, theorems related to Triangular, Symmetric and Skew-symmetric matrices, Idempotent matrices, Orthogonal matrices. Row-Echelon forms of a matrix, Gaussian Elimination Technique. Row space, column space and null space of a matrix. Rank of a matrix, Row-rank, Column-rank, standard theorems on Ranks. Nullity of a matrix, relationship between rank and nullity of a matrix.

Unit III: Determinants and System of Linear Equations [10L]

Definition, properties and applications of determinants for 3rd and higher orders, evaluation of determinants of order 3 and more using transformations. Symmetric and Skew symmetric determinants, product of determinants. The system of linear equations $\boldsymbol{Ax = b}$, conditions for consistency, uniqueness, infinite solutions, solution sets of linear equations, linear independence, Applications of linear equations. Use of determinants in solution to the system of linear equations. Adjoint and inverse of a matrix and related properties. Singular and non-singular matrices and their properties. Cayley-Hamilton theorem (without proof) and it's uses.

Unit IV: Eigen Analysis and Quadratic Forms [6L]

Characteristic polynomial and characteristic equation corresponding to a matrix. Characteristic roots and characteristic vectors, properties of characteristic roots and related results. Quadratic forms: Classification & canonical reduction.

Text & Reference books:

1. Hadley G. (2002): Linear Algebra. Narosa Publishing House (Reprint).
2. Searle, S. R. (1982): Matrix Algebra Useful for Statistics. John Wiley & Sons.
3. Chakraborty Arnab (2014): Linear Algebra, 1st Edition. Sarat Book House.
4. Gun A. M. (1988): Vectors and Matrices, World Press.
5. Schaum's Outlines (2006): Linear Algebra, Tata McGraw-Hill Edition, 3rd Edition.
6. Mapa S.K. (2011): Higher Algebra: Abstract and Linear, Sarat Book House, 12th Edition.

1090011202	MC3 – Linear Algebra LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Linear Algebra Theory				
Co-requisites	Use of scientific calculators				

Learning objectives:

To provide students the hands-on experience of different applications of vector and matrices.

Course learning outcomes*:*

***CO1*: Understand** vector subspaces and their graphical representations.
***CO2:* Solve** practical problems based on the vector subspaces, span, linear dependence and independence, basis.
***CO3:* Make use of** the knowledge of orthonormal bases for solving various problems arising in real life scenario.
***CO4:* Apply** the knowledge of the system of linear equations to solve various real life problems.
***CO5:* Solve** practical problems based on eigen-values, eigen-vectors of a matrix.
***CO6:* Apply** the knowledge of the quadratic forms to solve various real life problems.

Course Content:

List of experiments (to be executed using Scientific Calculators)

Sl. No.	Name of the Experiments
1	Problems based on vector subspaces.
2	Problems based on linear span, spanning set, linear dependence and independence.
3	Problems on finding bases and dimension of different subspaces.
4	Problems on finding Row-Echelon forms of a matrix and it's uses.
5	Problems based on Gram-Schmidt Orthogonalization Technique, finding orthonormal bases of subspaces.
6	Problems related to Determinant of Matrices.
7	Problems on solution to a linear system of equations.
8	Problems on Characteristic Roots and Characteristic Vectors.
9	Problems related to Quadratic Forms.

Text & Reference books:

1. Hadley G. (2002): Linear Algebra. Narosa Publishing House (Reprint).
2. Searle, S. R. (1982): Matrix Algebra Useful for Statistics. John Wiley & Sons.
3. Chakraborty Arnab (2014): Linear Algebra, First edition. Sarat Book House.
4. Gun A. M. (1988): Vectors and Matrices, World Press.
5. Schaum's Outlines (2006): Linear Algebra, Tata McGraw-Hill Edition, 3rd Edition.
6. Mapa S.K. (2011): Higher Algebra: Abstract and Linear, Sarat Book House, 12th Edition.

1090011104	MC4 – Probability II	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	**Probability I**				
Co-requisites	----				

Learning objectives:

- To help students in building knowledge of different discrete and continuous probability distributions along with their applications.
- To help students in forming the concepts of Bivariate Generating Functions, Trinomial and Bivariate Normal distributions along with their applications.

Course learning outcomes*:*

CO1: **Develop** the concepts of different discrete probability distributions with their properties and applications.
CO2: **Apply** the concepts of different continuous probability distributions with their properties and applications.
CO3: **Explain** the basic concepts of standard discrete and continuous truncated distributions.
CO4: **Build** the fundamental knowledge of two-dimensional random variables and its related properties.
CO5: **Develop** the concepts of bivariate generating functions along with its applications.
CO6: **Develop** the fundamental knowledge of Trinomial and Bivariate Normal distributions along with their applications.

Course Content:

Unit I: Standard discrete probability distributions **[10L]**

Discrete Uniform, Bernoulli, Binomial, Hypergeometric, Poisson, Geometric, Negative Binomial, Power Series. Limiting/approximation cases. Truncated distributions.

Unit II: Standard continuous probability distributions **[10L]**

Rectangular, Exponential, Double Exponential, Gamma, Beta, Normal, Lognormal, Cauchy, Logistic and Pareto along with their properties. Truncated distributions.

Unit III: Two dimensional Random Variables **[10L]**

Bivariate Random Variables and its properties, joint, marginal and conditional distributions, properties of joint Cumulative Distribution Function, independence of Random Variables, theorems on sum and product of expectations of Random Variables, conditional moments, Correlation and Regression. Bivariate Probability Generating Function (P.G.F.) and Bivariate Moment Generating Function (M.G.F.).

Unit IV: Trinomial and Bivariate Normal distributions **[6L]**

Trinomial distribution and its properties, Bivariate Normal distribution (BVN): p.d.f. of BVN, properties of BVN, marginal and conditional p.d.f. of BVN.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edition. World Press, Kolkata
2. Gun A.M., Gupta M.K. & Dasgupta, B. (1994): An Outline of Statistical Theory, Vol. I, World Press.
3. Gun A.M. and Roy D. (2006): Problems In Probability Theory, 2nd Edition, World Press.
4. Ross S. (2002): A First Course in Probability, Prentice Hall.
5. Feller W. (1968): An Introduction to Probability Theory & its Applications, John Wiley.
6. Uspensky J.V. (1937): Introduction to Mathematical Probability, McGraw Hill.

1090011203	MC4 – Probability II LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Probability II Theory				
Co-requisites	Use of scientific calculators				

Learning objectives:

To provide students the hands-on experience of fitting and application based problems of different standard discrete and continuous probability distributions.

Course learning outcomes*:*

***CO1*: Solve** numerical problems based on fitting of different standard discrete probability distributions.
***CO2:* Solve** application problems based on different standard discrete probability distributions.
***CO3:* Make use of** the knowledge of solving numerical problems based on fitting of Normal distribution.
***CO4:* Make use of** the knowledge of solving application problems based on Normal distribution.
***CO5:* Apply** the knowledge of other standard continuous probability distributions for solving its problems.
***CO6:* Apply** the knowledge of Trinomial and Bivariate Normal distributions for solving its problems.

Course Content:

List of experiments (to be executed using Scientific Calculators)

Sl. No.	Name of the Experiments
1	Fitting of Binomial distributions for n and p = q = ½.
2	Fitting of Binomial distributions for given n and p.
3	Fitting of Binomial distributions after computing mean and variance.
4	Fitting of Poisson distribution for given value of mean.
5	Fitting of Poisson distribution after computing mean.
6	Fitting of Negative Binomial distribution.
7	Fitting of suitable discrete distributions.
8	Application problems based on Binomial distribution.
9	Application problems based on Poisson distribution.
10	Application problems based on Negative Binomial distribution.
11	Problems based on area property of Normal distribution.
12	To find the ordinate for a given area for Normal distribution.
13	Application based problems using Normal distribution.
14	Fitting of Normal distribution when parameters are given.
15	Fitting of Normal distribution when parameters are not given.
16	Problems similar to the above five in cases of other continuous distributions.
17	Application based Problems on Trinomial distributions.
18	Application based Problems on Bivariate Normal distributions.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edition. World Press, Kolkata
2. Gun A.M., Gupta M.K. and Dasgupta, B. (1994): An Outline of Statistical Theory, Vol. I, World Press.
3. Gun A.M. and Roy D. (2006): Problems In Probability Theory, 2nd Edition, World Press.
4. Ross S. (2002): A First Course in Probability, Prentice Hall.
5. Feller W. (1968): An Introduction to Probability Theory & its Applications, John Wiley.
6. Uspensky J.V. (1937): Introduction to Mathematical Probability, McGraw Hill.

Semester III

1090012105	MC5 – Descriptive Statistics II	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Descriptive Statistics I				
Co-requisites	----				

Learning objectives:

- Acquire the knowledge about different measures of bivariate and categorical data analysis.
- Acquire the knowledge about different measures of multivariate data analysis.

Course learning outcomes*:*

CO1: **Build** knowledge about the concepts and results associated with correlation index and correlation ratios.
CO2: **Apply** the knowledge of intra-class correlation along with its associated properties.
CO3: **Explain** the concept of consistency and associations between attributes.
CO4: **Make use of** the knowledge about the different measures of association for 2×2 and $k \times l$ classifications.
CO5: **Explain** the basic ideas of multivariate data and various descriptive measures associated with it.
CO6: **Apply** the concepts about the different aspects of multivariate regression.

Course Content:

Unit I: Bivariate Data Analysis **[10L]**

Review of simple Correlation and simple linear Regression, Correlation Ratio, Correlation Index, Intra-class correlation.

Unit II: Categorical Data Analysis **[12L]**

Theory of attributes, data consistency, contingency tables, independence and association of attributes, measures of association for 2×2 case – Yule's measures, Risk Difference, Risk Ratio, Odds ratio. Manifold two-way $(k \times l)$ classification – Pearson's measures, Tschuprow's measure, Cramer's V^2, Goodman-Kruskal gamma, Somer's d, Kendall's measures.

Unit III: Multivariate Data Analysis **[14L]**

Multivariate data, mean vector, dispersion matrix and its properties. Multiple regression, multiple correlation, partial correlation coefficients, associated results.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edition. The World Press, Kolkata.
2. Agresti A. (2010): Analysis of Ordinal Categorical Data, 2nd Edition, Wiley.
3. Anderson T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rd Edition, John Wiley
4. Kshirsagar A.M. (1972): Multivariate Analysis, 1st Edition. Marcel Dekker.

1090012204	MC5 – Descriptive Statistics II LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Descriptive Statistics II Theory				
Co-requisites	Use of scientific calculators and/or Microsoft Excel				

Learning objectives:

To provide students the hands-on experience of different statistical methods relating the analysis of bivariate, categorical and multivariate statistical data.

Course learning outcomes*:*

CO1: **Solve** numerical problems based on correlation ratios and correlation index.
CO2: **Demonstrate** the use of intra-class correlation coefficient by solving its numerical problems.
CO3: **Make use of** the knowledge of solving numerical problems relating to analysis of categorical data for 2×2 classifications.
CO4: **Apply** the knowledge of solving numerical problems relating to analysis of categorical data for $k \times l$ classifications.
CO5: **Solve** numerical problems based on multiple linear regression.
CO6: **Solve** numerical problems based on multiple and partial correlation coefficients.

Course Content:

List of experiments (to be executed using Scientific Calculators and/or MS Excel)

Sl. No.	Name of the Experiments
1	Problems based on analysis of Bivariate data.
2	Problems based on Correlation Ratio and Correlation Index.
3	Problems based on Intra-class Correlation.
4	Problems based on measures of Categorical data for 2×2 classifications.
5	Problems based on measures of Categorical data for $k \times l$ classifications.
6	Problems based on mean vector and dispersion matrix.
7	Problems based on multiple regression, multiple correlation and partial correlation coefficients.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8th Edition. The World Press, Kolkata.
2. Agresti A. (2010): Analysis of Ordinal Categorical Data, 2nd Edition, Wiley.
3. Anderson T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rd Edition, John Wiley
4. Kshirsagar A.M. (1972): Multivariate Analysis, 1st Edition. Marcel Dekker.

1090012106	MC6 – Sampling Distributions	C	L	T	P
Version 1.0	**Contact Hours – 60**	5	5	0	0
Pre-requisites/Exposure	Probability I & Probability II				
Co-requisites	----				

Learning objectives:

- Develop a basic idea about the concepts of sampling distributions of a statistic.
- Acquire the knowledge about the exact sampling distributions - $\chi 2$, t and F.
- Make use of the knowledge about finding sampling distributions from Bivariate Normal population.
- Build an idea of solving problems related to Order Statistics.

Course learning outcomes*:*

CO1: **Demonstrate** the basic concepts of sampling theory and sampling distributions of a statistic.
CO2: **Develop** knowledge on the exact sampling distribution – $\chi 2$.
CO3: **Develop** knowledge on the exact sampling distributions – Fisher's and Student's t.
CO4: **Build** knowledge on the exact sampling distribution – F.
CO5: **Illustrate** the method of finding sampling distributions from Bivariate Normal population.
CO6: **Solve** problems related to order statistics and distributions of sample median and sample range.

Course Content:

Unit I: Basic concepts of sampling distributions **[12L]**

Concepts of Population & Parameter, Random Sample & Statistic. Types of Population & Sampling. Sampling Distribution of a Statistic and its numerical applications. Sampling Fluctuations & Standard Error of a Statistic. Techniques of obtaining Sampling Distributions of functions of random variables – CDF technique, Generating Functions technique, Transformation of variables technique with examples.

Unit II: Exact sampling distributions **[22L]**

χ^2 distribution: definition and derivation of its p.d.f. with 'n' degrees of freedom (d.f.), nature of p.d.f. curve for different degrees of freedom, mean, variance, m.g.f., additive property of χ^2 distribution. Derivation of the sampling distribution of sample mean and variance for a Normal population.

Fisher's and Student's t distributions: derivation of its p.d.f., nature of probability curve with different degrees of freedom, mean, variance and limiting form of t distribution.

Snedecor's F distribution: derivation of p.d.f., nature of p.d.f. curve with different degrees of freedom, mean, variance. Distribution of $1/F_{n_1,n_2}$. Relationship between t, F and χ^2 distributions.

Unit III: Sampling from Bivariate Normal population **[16L]**

Distributions of sample means, sample variances and sample correlation coefficient (null case) of a random sample from a Bivariate Normal population, distribution of the simple regression coefficient (for both stochastic and non-stochastic independent variable cases).

Unit IV: Order Statistics **[10L]**

Introduction, distribution of the r^{th} Order Statistic, smallest and largest Order Statistics. Joint distribution of Order Statistics, distribution of sample median and sample range. Applications.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2003): An Outline of Statistical Theory, Vol. I, 4th Edition., World Press, Kolkata.
2. Rohatgi V. K. and Saleh A.K. Md. E. (2009): An Introduction to Probability and Statistics, 2nd Edition. (Reprint), John Wiley and Sons.
3. Mood A.M., Graybill F.A. and Boes D.C. (2007): Introduction to the Theory of Statistics, 3rd Edition. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
4. Hogg R.V. & Craig A.T. (1978): Introduction to Mathematical Statistics, Prentice Hall.
5. Gun A.M. and Roy D. (2006): Problems In Probability Theory, 2nd Edition, World Press.

Semester IV

1090013107	MC7 – Statistical Inference I	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Probability I, Probability II & Sampling Distributions				
Co-requisites	----				

Learning objectives:

Statistical Inference deals with the theory, methods and practice of forming judgements about the parameters of a population and the reliability of statistical relationships, typically on the basis of random sampling. Main objectives of this course are:

- To develop the concepts regarding the process of using data analysis to infer properties of an underlying distribution of probability.
- Students will learn how to make predictions and draw conclusions about a population based on limited information, which is often the case in real-world problems.

Course learning outcomes:

CO1: **Explain** the introductory concepts of the theory of point estimation and testing of hypothesis.
CO2**: Apply** the concepts of sufficiency in explanatory data analysis.
CO3: **Make use** of the knowledge of unbiasedness and minimum variance in any explanatory data analysis.
CO4: **Apply** different methods of estimation techniques in different real life inferential aspects.
CO5: **Build** an idea for the requirement of different methods of estimation techniques and different procedures of hypothesis testing in different real life scenario.
CO6: **Make use** of the knowledge of different testing problems to give valid conclusions for different real life problems.

Course Content:

UNIT I: Introduction to Statistical Inference **[4L]**

Prerequisites: Population, parameter and parameter space, sample and sample space, statistic, sampling distribution and standard error. Different methods of statistical inference – Estimation and Testing of Hypothesis.

UNIT II: Point Estimation **[14L]**

Concepts of point estimation, estimator and estimate, requirements of good estimator: Closeness, Unbiasedness and Minimum variance. Sufficiency, Neyman-Fisher Factorization Theorem and its uses. Uniformly Minimum variance unbiased estimator (UMVUE), Correlation between UMVUE and other unbiased estimators. Concept of Completeness (Only definition), One Parameter Exponential Family (OPEF), Cramer-Rao inequality and MVB estimators. Rao-Blackwell and Lehmann-Scheffe theorems and their applications.

UNIT III: Methods of Estimation **[6L]**

Method of Moments, method of Least Square and method of maximum likelihood estimation, method of minimum Chi-square, derivation of maximum likelihood estimation for the parameters of standard statistical distributions.

UNIT IV: Basic Notions of Hypothesis Testing **[12L]**

Basic principles of hypothesis testing, null and alternative hypotheses, simple and composite hypotheses, critical region and acceptance region. Definition of a test function, Type – I and Type – II errors and their probabilities, level of significance, size, power of a test. Power function of a test for composite alternatives and power curves. Testing problems related to univariate populations (binomial, poisson, normal, exponential etc.), two independent populations and bivariate normal population.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol. I, 8th Edition. World Press, Kolkata.
2. Rohatgi V. K. and Saleh A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edition. (Reprint) John Wiley and Sons, INC.
3. Gun A.M., Gupta M.K. and Dasgupta B.: An Outline of Statistical Theory, Vol. II, The World Press Private Limited, Kolkata.
4. Casella G., Berger RL.: Statistical Inference, Second Edition, Cengage Learning India Private Limited.
5. Kale B.K., Muralidharan K.: Parametric Inference An Introduction, Narosa Publishing House.
6. Mood A.M., Graybill F.A., Boes D.C.: Introduction To The Theory Of Statistics, 3rd Edition, Tata McGraw-Hill Publishing Company Limited.

1090013205	MC7 – Statistical Inference I LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Statistical Inference I Theory				
Co-requisites	Use of scientific calculators and use of different statistical tables				

Learning objectives:

To provide the students the hands-on experience of the different aspects of explanatory data analysis by applying the different inferential techniques on real life data sets and comparing them.

Course learning outcomes*:*

CO1: **Solve** practical problems based on the unbiasedness and minimum variance.
CO2: **Solve** practical problems based on finding sufficient statistics.
CO3: **Solve** practical problems based on UMVUE.
CO4: **Solve** practical problems based on MLE.
CO5: **Make use of** the knowledge of Cramer Rao Inequality to find a lower bound to an unbiased estimator in regular estimation cases.
CO6: **Apply** the knowledge of the hypothesis testing to solve various real life problems.

Course Content:

List of experiments (to be executed using Scientific Calculators & Statistical Tables)

Sl. No.	Name of the Experiments
1	Problems based on finding unbiased estimators and comparing two or more unbiased estimators based on their variances.
2	Problems based on verifying sufficiency of different statistics, finding sufficient statistics using Neyman-Fisher Factorization Theorem.
3	Problems on finding Cramer-Rao lower bounds for different unbiased estimators under regular estimation case.
4	Problems based on Maximum Likelihood Estimation and Method of Moments.
5	Problems based on calculating size, power and drawing power curves for different tests.
6	Testing problems related to univariate populations.
7	Testing problems related to two independent univariate populations.
8	Testing problems related to a bivariate normal distribution.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol. I, 8th Edition. World Press, Kolkata.
2. Rohatgi V. K. and Saleh A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edition. (Reprint) John Wiley and Sons, INC.

3. Gun A.M., Gupta M.K. and Dasgupta B.: An Outline of Statistical Theory, Vol. II, The World Press Private Limited, Kolkata.
4. Casella G., Berger RL.: Statistical Inference, Second Edition, Cengage Learning India Private Limited.
5. Kale B.K., Muralidharan K.: Parametric Inference An Introduction, Narosa Publishing House.
6. Mood A.M., Graybill F.A., Boes D.C.: Introduction To The Theory Of Statistics, 3rd Edition, Tata McGraw-Hill Publishing Company Limited.

1090013108	MC8 – Economic Statistics	C	L	T	P
Version 1.0	**Contact Hours – 48**	4	4	0	0
Pre-requisites/Exposure	Degree Level Statistics and Basic Mathematics Knowledge				
Co-requisites	----				

Learning objectives:

To provide students the fundamental knowledge of different statistical methods of Index Numbers, Income Inequality and Time Series analysis along with their applications.

Course learning outcomes:

CO1: **Build** the concepts of various index numbers with their uses.
CO2: **Build** the concepts of the measurements of income inequality.
CO3: **Develop** the concepts of different components and models of a time series data.
CO4: **Estimate** the trend component using different methods.
CO5: **Estimate** the seasonal component using different methods.
CO6: **Utilize** moving average and auto regressive processes in forecasting.

Course Content:

Unit I: Index Numbers and Income Inequality [13L]

Weighted means, Price and Quantity Index Numbers, Value Index, Construction, Uses, Limitations, Laspeyres' and Paasche's Index Numbers. Tests of Index Numbers and Fisher's ideal Index Number, Chain Index Number. Consumer Price Index Number, Wholesale Price Index Number and Index Number of Industrial Production – methods of construction and uses.
Measurement of income inequality: Gini's coefficient, Lorenz curve, Application of Pareto and Lognormal as income distributions.

Unit II: Introduction to Time Series and Estimation of Trend [11L]

Introduction, application of Time Series from various fields. Modelling Time Series as deterministic function plus i.i.d. errors. Components of a Time Series (Trend, Seasonal and Cyclical patterns, Random error). Decomposition of Time Series - Additive and Multiplicative models. Estimation of Trend: Free hand curve method, method of Moving Averages, fitting various Mathematical Curves and Growth Curves. Detrending. Effect of elimination of Trend on other components of the Time Series.

Unit III: Estimation of Seasonal Component and Introduction to Stochastic Modelling [11L]

Estimation of Seasonal component by Method of Simple Averages, Ratio-to-Moving Average, Ratio-to-Trend. Deseasonalization. Introduction to Stochastic modelling: Concept of Stationarity. Illustration of how a Stationary Time Series may show temporal patterns. Stationarity in mean. Auto-covariance (ACVF) and Auto-correlation functions (ACF) and their properties.

Unit IV: Box-Jenkins modelling and Forecasting [13L]

Moving-average (MA) process and Autoregressive (AR) process of orders one and two. ACF and its graphical use in guessing the order of MA processes. Estimation of the parameters of AR (1) and AR (2) using Least Square and Yule-Walker equations. Introduction to ARMA and ARIMA models. Forecasting: Exponential Smoothing methods.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol. II, 8th Edition, The World Press Private Limited, Kolkata.
2. Allen R.G.D. (1975): Index Numbers in Theory and Practice, Macmillan.
3. Nagar A.L. and Das R.K. (1997): Basic Statistics, 2nd Edition, Oxford University Press.
4. Brockwell and Davis (2010): Introduction to Time Series and Forecasting (Springer Texts in Statistics), 2nd Edition.
5. Chatfield C. (1980): The Analysis of Time Series – An Introduction, Chapman & Hall.
6. Mukhopadhyay P. (1999): Applied Statistics, Books & Allied Pvt. Ltd.
7. Kendall M.G. (1976): Time Series, Charles Griffin.

1090013206	MC8 – Economic Statistics LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Economic Statistics Theory				
Co-requisites	Use of scientific calculators and/or Microsoft Excel				

Learning objectives:

To provide students the hands-on experience of different statistical methods of Index Numbers, Income Inequality and Time Series analysis along with their applications.

Course learning outcomes:

CO1: **Solve** numerical problems based on computations of different index numbers along with their tests for consistency.
CO2: **Make use of** the knowledge for solving numerical problems related to the measurement of income inequality.
CO3: **Interpret** time series data through different graphical representations in order to detect various features.
CO4: **Estimate** the trend component of a time series data with the help of moving average and mathematical curve fitting methods.
CO5: **Estimate** the seasonal component of a time series data with the help of ratio-to-moving average and ratio-to-trend methods.
CO6: **Utilize** moving average and auto regressive processes in forecasting a time series data.

Course Content:

List of experiments (to be executed using Scientific Calculators and/or MS Excel)

Sl. No.	Name of the Experiments
1	Problems based on calculation of Price and Quantity Index Numbers.
2	Problems based on applications of Chain Index Numbers.
3	Problems based on construction of Consumer and Wholesale Price Index Numbers.
4	Problems based on measurement of Income Inequality.
5	Problems based on plotting a real-life Time Series data and detecting various features (Trend, periodic behaviours etc.)
6	Problems based on estimation of Trend by Moving Average method.
7	Problems based on fitting and plotting of mathematical curves: Linear, Parabolic, Exponential and Modified Exponential.
8	Problems based on measurement of Seasonal indices Ratio-to-Moving Average method.
9	Problems based on measurement of Seasonal indices Ratio-to-Trend method.
10	Problems based on plotting ACF of a given Time Series data.
11	Problems based on use of Yule-Walker equations and Least squares to fit AR(1) and AR(2) models to real life data.
12	Problems based on forecasting by Exponential Smoothing method.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. II, 8th Edition. The World Press Private Limited, Kolkata.
2. Allen R.G.D. (1975): Index Numbers in Theory and Practice, Macmillan.
3. Nagar A.L. and Das R.K. (1997): Basic Statistics, 2nd Edition, Oxford University Press.
4. Brockwell and Davis (2010): Introduction to Time Series and Forecasting (Springer Texts in Statistics), 2nd Edition.
5. Chatfield C. (1980): The Analysis of Time Series – An Introduction, Chapman & Hall.
6. Mukhopadhyay P. (1999): Applied Statistics, Books & Allied Pvt. Ltd.
7. Kendall M.G. (1976): Time Series, Charles Griffin.

Semester V

1090014109	MC9 – Statistical Inference II	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Probability I, Probability II, Sampling Distributions and Statistical Inference I				
Co-requisites	----				

Learning objectives:

Statistical Inference deals with the theory, methods and practice of forming judgements about the parameters of a population and the reliability of statistical relationships, typically on the basis of random sampling. Main objectives of this course are:

- To develop the concepts regarding the process of using data analysis to infer properties of an underlying distribution of probability when it is completely unknown.
- Students will learn how to make predictions and draw conclusions about a population based on limited information, which is often the case in real-world problems.
- To approximate the distribution of the statistic of interest when the sample size is large.

Course learning outcomes:

CO1: **Build** the knowledge of optimum testing procedures which can be applied in any explanatory data analysis.
CO2: **Make use** of the knowledge of Fundamental Neyman-Pearson lemma to find most powerful and uniformly most power tests.
CO3: **Explain** the advantages of applying uniformly most powerful tests and likelihood ratio tests in different real life scenario.
CO4: **Apply** the concepts of confidence intervals and tests in different real life inferential aspects.
CO5: **Make use** of the knowledge of finding confidence intervals using the method of pivots.
CO6: **Explain** the advantages of shortest-length confidence intervals.

Course Content:

UNIT I: Some Optimum Tests and methods to obtain Optimum Tests [16L]

Non-randomized and randomized tests. Definition of more powerful, Most Powerful (MP), Uniformly Most Powerful (UMP) tests. Construction of MP tests: Fundamental Neyman-Pearson lemma. Construction of UMP tests. Unbiased tests and biased tests, definition of Uniformly Most Powerful Unbiased (UMPU) test.

UNIT II: Generalized Likelihood Ratio Tests [8L]

Definition of Likelihood Ratio Test (LRT) and its properties. Obtaining LRT for one sample, two sample and multi-sample problems under normal populations and some non-normal populations.

UNIT III: Confidence Estimation **[12L]**

Definition of confidence sets, confidence level and confidence coefficient. Confidence interval as a special case of confidence set. Finding confidence intervals for Binomial proportions, for univariate normal mean, variance, for population correlation coefficient for Bivariate Normal distribution etc. Pivotal quantity method of constructing confidence intervals. Shortest length confidence interval and it's expected length. Relationship of confidence estimation with testing of hypothesis, definition of MA, UMA and UMAU confidence sets.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol. I, 8th Edition, The World Press Private Limited, Kolkata.
2. Rohatgi V. K. and Saleh A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edition. (Reprint) John Wiley and Sons, INC.
3. Gun A.M., Gupta M.K. and Dasgupta B.: An Outline of Statistical Theory, Vol. II, The World Press Private Limited, Kolkata.
4. Casella G., Berger RL.: Statistical Inference, Second Edition, Cengage Learning India Private Limited.
5. Kale B.K., Muralidharan K.: Parametric Inference An Introduction, Narosa Publishing House.
6. Mood A.M., Graybill F.A., Boes D.C.: Introduction To The Theory Of Statistics, 3rd Edition, Tata McGraw-Hill Publishing Company Limited.

1090014207	MC9 – Statistical Inference II LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Statistical Inference II Theory				
Co-requisites	Use of scientific calculators and use of different Statistical Tables				

Learning objectives:

To provide the students the hands-on experience of the different aspects of explanatory data analysis by applying the different inferential techniques on real life data sets and comparing them.

Course learning outcomes*:*

CO1: **Solve** practical problems based on the MP and UMP tests.
CO2: **Solve** practical problems based on finding likelihood ratio tests for single univariate parametric families.
CO3: **Solve** practical problems based on finding likelihood ratio tests for two independent univariate parametric families.
CO4: **Solve** practical problems based on finding confidence intervals based on pivots for single univariate parametric families.
CO5: **Solve** practical problems based on finding confidence intervals based on pivots for two independent univariate parametric families.
CO6: **Apply** the knowledge of shortest length confidence interval to solve various real life problems.

Course Content:

List of experiments (to be executed using Scientific Calculators & Statistical Tables)

Sl. No.	Name of the Experiments
1	Problems based on finding MP tests and UMP tests for different parametric family of distributions.
2	Problems based on finding likelihood ratio tests related to a single univariate population.
3	Problems based on finding likelihood ratio tests related to two independent univariate populations.
4	Problems on finding confidence intervals using pivots for a single univariate population.
5	Problems on finding confidence intervals using pivots for two independent univariate populations.
6	Problems based on finding shortest length confidence intervals.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol. I, 8th Edition, The World Press Private Limited, Kolkata.

2. Rohatgi V. K. and Saleh A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edition. (Reprint) John Wiley and Sons, INC.
3. Gun A.M., Gupta M.K. and Dasgupta B.: An Outline of Statistical Theory, Vol. II, The World Press Private Limited, Kolkata.
4. Casella G., Berger RL.: Statistical Inference, Second Edition, Cengage Learning India Private Limited.
5. Kale B.K., Muralidharan K.: Parametric Inference An Introduction, Narosa Publishing House.
6. Mood A.M., Graybill F.A., Boes D.C.: Introduction To The Theory Of Statistics, 3rd Edition, Tata McGraw-Hill Publishing Company Limited.

1090014110	MC10 – Linear Models	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Linear Algebra and Statistical Inference I				
Co-requisites	----				

Learning objectives:

To introduce the students with the basic theory of linear estimation, Simple and Multiple Regression Models, ANOVA and ANCOVA Models and finally use some tools to test the model validity.

Course learning outcomes:

CO1: **Demonstrate** the concepts of Gauss-Markov set-up.
CO2: **Explain** the fundamental concepts of testing linear hypothesis, orthogonal splitting and valid error.
CO3: **Make use of** the method of least squares in simple and multiple regression models.
CO4: **Apply** the knowledge of different tests in simple and multiple regression set-up.
CO5: **Construct** analysis of variance models to test the significance of several means.
CO6: **Construct** analysis of covariance models to test the significance of several means.

Course Content:

Unit I: Gauss-Markov set-up **[8L]**

Introduction to linear models, classification, theory of linear estimation, estimability of linear parametric functions, method of least squares, Gauss-Markov theorem, estimation space and error space, estimation of error variance, fundamental theorems on least squares (statements only), linear hypothesis and its testing, orthogonal splitting of total variation, selection of valid error.

Unit II: Regression Analysis and Regression Diagnostics **[10L]**

Simple and Multiple regression analysis, estimation and hypothesis testing in case of simple and multiple regression models, tests for parallelism and identity, linearity of simple regression. Model checking: prediction from a fitted model.

Unit III: Analysis of Variance **[12L]**

Definitions of fixed, random and mixed effect models, analysis of variance in one-way classified data for fixed effect models, analysis of variance in two-way classified data (with one observation per cell and more than one but equal observations per cell) for fixed effect models, analysis of variance in one-way classified data for random effect models.

Unit IV: Analysis of Covariance **[6L]**

Analysis of covariance (with one concomitant variable) in one-way classified data, analysis of covariance (with one concomitant variable) in two-way classified data.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. II, 8th Edition, The World Press Private Limited, Kolkata.
2. Scheffe H. (1959): The Analysis of Variance, John Wiley.
3. Rao C.R. (2009): Linear Statistical Inference and its Applications, 2nd Edition, John Wiley & Son, Inc.
4. Faraway J.J. (2014): Linear Models with R, 2nd Edition, CRC Press.
5. Gupta S.C. and Kapoor V.K. (1975): Fundamentals of Applied Statistics: A Modern Approach, S. Chand & Company.

1090014208	MC10 – Linear Models LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Linear Models Theory				
Co-requisites	Use of scientific calculators, different Statistical Tables and/or Microsoft Excel				

Learning objectives:

To provide students with the computational knowledge in fitting different types of Linear Models – Regression, ANOVA, ANCOVA and interpreting the result.

Course learning outcomes:

CO1: **Solve** numerical problems based on estimability and testing of linear hypothesis.
CO2: **Make use of** the knowledge for solving problems related to simple linear regression.
CO3: **Apply** problem solving knowledge related to multiple linear regression.
CO4: **Analyze** the data arising out a one way classified data under fixed and random effect models.
CO5: **Analyze** the data arising out a two way classified data (with one observation and more than one but equal observations per cell) under fixed effect models.
CO6: **Solve** numerical problems based on the analysis of covariance of one and two way classified data having one concomitant variable.

Course Content:

List of experiments (to be executed using Scientific Calculators, Statistical Tables and/or MS Excel)

Sl. No.	Name of the Experiments
1	Problems based on estimability when X is a full rank matrix and not a full rank matrix.
2	Problems based on tests for linear hypothesis.
3	Problems based on simple linear regression.
4	Problems based on multiple linear regression.
5	Problems based on presence and linearity of simple regression.
6	Problems based on parallelism and identity of a number of regression lines.
7	Problems based on analysis of variance of a one way classified data for fixed effects models.
8	Problems based on analysis of variance of a two way classified data with one observation per cell for fixed effects models.
9	Problems based on analysis of variance of a two way classified data with more than one but equal observations per cell for fixed effects models.
10	Problems based on analysis of variance of a one way classified data for random effects models.
11	Problems based on analysis of covariance of a one way classified data with one concomitant variable.
12	Problems based on analysis of covariance of a two way classified data with one concomitant variable.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. II, 8th Edition, The World Press Private Limited, Kolkata.
2. Scheffe H. (1959): The Analysis of Variance, John Wiley.
3. Rao C.R. (2009): Linear Statistical Inference and its Applications, 2nd Edition, John Wiley & Son, Inc.
4. Faraway J.J. (2014): Linear Models with R, 2nd Edition, CRC Press.
5. Gupta S.C. and Kapoor V.K. (1975): Fundamentals of Applied Statistics: A Modern Approach, S. Chand & Company.

1090014111	MC11 – Numerical Analysis Using C++	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Knowledge of basic Mathematics and Statistics				
Co-requisites	----				

Learning objectives:

- To help the students in building knowledge about inaccuracies and approximations, interpolation, numerical differentiation, numerical integration, numerical solution of equations and solution of system of equations by numerical methods.
- To help the students in getting acquainted with the basics of C environment, different decision making statements and looping structures, knowledge of Arrays and Functions and their uses in writing programs.

Course learning outcomes:

CO1: **Understand** the theoretical aspects of the use of numerical methods along with its advantages and limitations.
CO2: **Apply** the idea of interpolation, numerical differentiation and integration.
CO3: **Build** the concepts of numerical solution of equations and solution of system of linear algebraic equations.
CO4: **Explain** the basic notions of character set, data types, keywords, identifiers, operators and expressions in a C environment.
CO5: **Build** knowledge about the different decision making statements and looping structures in a C environment.
CO6: **Understand** how to use arrays and user defined functions while writing a C program.

Course Content:

Unit I: Introduction to Numerical Analysis and Interpolation [8L]

Approximation of numbers and functions, Absolute and Relative errors. Interpolation: polynomial approximation, Weierstrass theorem (statement), finite differences, use of operators. Newtown's forward and backward interpolation formula, Lagrange's general interpolation formula, error terms. Divided differences, Newton's divided difference formula. Bivariate interpolation.

Unit II: Numerical differentiation and integration [4L]

Numerical differentiation and its applications. Numerical Integration: Trapezoidal and Simpson's $1/3^{rd}$ rules.

Unit III: Numerical solution of equations and system of equations [8L]

Method of bisection, method of fixed-point Iteration, Newton-Raphson method. Conditions of convergence, rates of convergence. Stirling's approximation to factorial 'n'.

Gauss-Elimination method, Gauss-Jacobi Iteration method and Gauss-Seidel Iteration method.

Unit IV: Basics of C Programming **[8L]**

Components, basic structure programming, character set, C/C++ tokens, Keywords and Identifiers and execution of a C/C++ program. Data types: Basic data types, Enumerated data types, derived data types. Constants and variables: declaration and assignment of variables, Symbolic Constants, overflow and underflow of data. Operators and Expressions: Arithmetic, relational, logical, assignment, increment/decrement operators, precedence of operators in arithmetic, relational and logical expression. Implicit and explicit type conversions in expressions, library functions. Managing input and output operations: reading and printing formatted and unformatted data.

Unit V: Loops, Arrays and Functions in C **[8L]**

Decision making and branching: if...else, nesting of if...else, else if ladder, switch. Looping in C/C++: for, nested for, while, do...while, and jumps in and out of loops. Arrays: declaration and initialization of one-dim and two-dim arrays. Character arrays and strings: declaring and initializing string variables, reading and writing strings from Terminal (using scanf and printf only). User-defined functions: a multi-function program using user-defined functions, definition of functions, return values and their types, function prototypes and calls. Category of Functions: no arguments and no return values, arguments but no return values, arguments with return values, no arguments but returns a value, functions that return multiple values.

Text & Reference books:

1. Scarborough J. B. (1966): Numerical Mathematical Analysis. Oxford and IBH Publishing
2. Sastry S. S. (2000): Introductory Methods of Numerical Analysis, 3rd edition, Prentice Hall of India Pvt. Ltd., New Delhi.
3. Mukherjee Kr. Kalyan (1990): Numerical Analysis. New Central Book Agency.
4. Mollah S.A. (2021): Numerical Analysis and Computational Procedures, 7th Edition, Books & Allied Pvt. Ltd.
5. Balagurusamy E. (2011): Programming in ANSI C, 6th Edition, Tata McGraw Hill.
6. Kernighan B. W. and Ritchie D. (1988): C Programming Language, 2nd Edition, Prentice Hall.
7. Kanetkar Y. (1995): Let Us C, 2nd Edition, BPB Publications.

1090014209	MC11 – Numerical Analysis Using C++ LAB	C	L	T	P
Version 1.0	**Contact Hours – 48**	2	0	0	4
Pre-requisites/Exposure	Numerical Analysis Using C++ Theory				
Co-requisites	----				

Learning objectives:

- To provide students the hands-on experience about different numerical methods relating to inaccuracies and approximations, interpolation, numerical differentiation, numerical integration, numerical solution of equations and solution of system of equations.
- To provide students the hands-on experience of writing programs related to different statistical methodologies using a C++ environment.

Course learning outcomes:

CO1: **Create** codes using C programming for solving numerical problems related to different interpolation formulae.
CO2: **Build** codes using C programming for solving problems related to numerical integration.
CO3: **Solve** numerical problems based on numerical solution of equations and solution of system of equations using C programming.
CO4: **Create** codes using C programming for solving problems related to the computations of univariate and bivariate statistical measures for ungrouped and grouped data setup.
CO5: **Build** codes using C programming for solving problems related to fitting of probability distributions.
CO6: **Solve** numerical problems using C programming related to matrix operations and random number generations.

Course Content:

List of experiments (to be executed using C++ compiler)

Sl. No.	Name of the Experiments
1	Problems based on based on Newtown's forward and backward, Lagrange's interpolation formula, Newton's divided difference formula.
2	Problems based on numerical integration: Trapezoidal's and Simpson's 1/3rd rule.
3	Problems based on solving one-variable equations using the methods of Bisection, Iteration and Newton-Raphson.
4	Problems based on solution of system of equations using Gauss-Elimination method, Gauss-Jacobi Iteration method and Gauss-Seidel Iteration method.
5	Problems based on calculation of univariate statistical measures from a given ungrouped data set.
6	Problems based on calculation of bivariate statistical measures from a given ungrouped data set.
7	Problems based on preparing a grouped frequency distribution.

8	Problems based on calculation of univariate statistical measures from a given grouped frequency data.
9	Problems based on fitting of Binomial and Poisson distributions.
10	Problems based on matrix addition, subtraction, multiplication, transpose, trace, rank, determinant and inverse.
11	Problems based on random number generation from a given probability distribution.

Text & Reference books:

1. Scarborough J. B. (1966): Numerical Mathematical Analysis. Oxford and IBH Publishing
2. Sastry S. S. (2000): Introductory Methods of Numerical Analysis, 3rd edition, Prentice Hall of India Pvt. Ltd., New Delhi.
3. Mukherjee Kr. Kalyan (1990): Numerical Analysis. New Central Book Agency.
4. Mollah S.A. (2021): Numerical Analysis and Computational Procedures, 7th Edition, Books & Allied Pvt. Ltd.
5. Balagurusamy E. (2011): Programming in ANSI C, 6th Edition, Tata McGraw Hill.
6. Kernighan B. W. and Ritchie D. (1988): C Programming Language, 2nd Edition, Prentice Hall.
7. Kanetkar Y. (1995): Let Us C, 2nd Edition, BPB Publications.

Semester VI

1090015112	MC12 – Design of Experiments	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Linear Models				
Co-requisites	----				

Learning objectives:

To introduce the students with the concepts of basic and advanced designs, factorial experiments and confounding which serves as multipurpose tools used in many situations to optimize the output.

Course learning outcomes:

CO1: **Define** the concept of design of experiment and its various related terminologies.
CO2: **Compare** the relative efficiencies of different designs.
CO3: **Develop** the concepts of basic designs, factorial experiments and confounding.
CO4: **Construct** ANOVA table and test statistics for various designs.
CO5: **Demonstrate** the applications of split plot and strip plot designs.
CO6: **List** the practical applicability of each of the designs.

Course Content:

Unit I: Introduction to experimental designs **[6L]**

Role, historical perspective, terminologies: treatments, experimental units & blocks, experimental error, basic principles of design of experiments (Fisher), uniformity trials, fertility contour maps, choice of size and shape of plots and blocks in agricultural experiments, uses in industrial experiments.

Unit II: Basic designs **[12L]**

Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model and statistical analysis, relative efficiency. Analysis with one missing observation in RBD and LSD.

Unit III: Factorial experiments and Confounding **[12L]**

Factorial experiments: advantages, notations and concepts. 2^n experiments: design and analysis. Total and Partial confounding for 2^n $(n \leq 5)$. Factorial experiments in a single replicate.

Unit IV: Split and Strip Plot designs **[6L]**

Split Plot design in RBD and Strip arrangements. Applications.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2005): Fundamentals of Statistics. Vol. II, 8th Edition. World Press, Kolkata.
2. Kempthorne O. (1965): The Design and Analysis of Experiments. John Wiley.
3. Montgomery D. C. (2008): Design and Analysis of Experiments, John Wiley.
4. Cochran W.G. and Cox G.M. (1959): Experimental Design. Asia Publishing House.
5. Das M.N. and Giri N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd.
6. S.C Gupta, V.K Kapoor (2000): Fundamentals of Applied Statistics, 3rd Edition, Sultan Chand and Sons, New Delhi.
7. Faraway J.J. (2014): Linear Models with R, 2nd Edition, CRC Press.

1090015210	MC12 – Design of Experiments LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Design of Experiments Theory				
Co-requisites	Use of scientific calculators				

Learning objectives:

To introduce the students with the various applications of the theoretical concepts of design of experiments in practical field, construction of ANOVA table for various designs and make conclusions for that.

Course learning outcomes:

CO1: **Identify** the problems based on different basic designs and factorial experiments.
CO2: **Model** for required designs of the given data.
CO3: **Explain** the theoretical basis of the given problems.
CO4: **Solve** the given problems as per data and requirement.
CO5: **Interpret** the final results of each of the problems.
CO6: **Construct** ANOVA tables and compute test statistics for various designs.

Course Content:

List of experiments (to be executed using Scientific Calculators)

Sl. No.	Name of the Experiments
1	Problems based on analysis of a Completely Randomized Design (CRD).
2	Problems based on analysis of a Randomized Block Design (RBD).
3	Problems based on analysis of a Latin Square Design (LSD).
4	Problems based on analysis of a Randomized Block Design (RBD) with one missing observation.
5	Problems based on analysis of a Latin Square Design (LSD) with one missing observation.
6	Problems based on analysis of 2^2 and 2^3 factorial experiment in CRD and RBD.
7	Problems based on analysis of a completely confounded two-level factorial design in 2 blocks.
8	Problems based on analysis of a completely confounded two-level factorial design in 4 blocks.
9	Problems based on analysis of a partially confounded two-level factorial design.
10	Problems based on analysis of a single replicate of a 2^n design.
11	Problems based on analysis of Split Plot design.
12	Problems based on analysis of Strip Plot design.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2005): Fundamentals of Statistics. Vol. II, 8th Edition. World Press, Kolkata.
2. Kempthorne O. (1965): The Design and Analysis of Experiments. John Wiley.

3. Montgomery D. C. (2008): Design and Analysis of Experiments, John Wiley.
4. Cochran W.G. and Cox G.M. (1959): Experimental Design. Asia Publishing House.
5. Das M.N. and Giri N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd.
6. S.C Gupta, V.K Kapoor (2000): Fundamentals of Applied Statistics, 3rd Edition, Sultan Chand and Sons, New Delhi.
7. Faraway J.J. (2014): Linear Models with R, 2nd Edition, CRC Press.

1090015113	MC13 – Survey Sampling	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Statistical Inference I				
Co-requisites	----				

Learning objectives:

To provide students with an exposure to the applications different survey sampling procedures in real-life situations.

Course learning outcomes:

CO1: **Explain** the introductory concepts related to survey sampling.
CO2: **Build** knowledge about Simple Random Sampling (SRS) and its applications.
CO3: **Make use of** the knowledge about Stratified Random Sampling (STRS) and its applications.
CO4: **Make use of** the knowledge of Systematic Sampling (SYS) and its applications in real-life scenarios.
CO5: **Build** knowledge about Ratio & Regression methods of estimation in real-life scenarios.
CO6: **Apply** the concepts of Cluster and Two-stage Sampling to different situations.

Course Content:

Unit I: Introduction to Survey Sampling [6L]

Concepts of Population and Sample, Sampling and its need, Types of Population and Sampling, Basic principles of Survey Sampling, Complete Enumeration versus Sampling, Stages in large-scale Survey Sampling, Sampling and Non-sampling Errors, Technique of Random Sampling – use of a Random Sampling Number Series.

Unit II: Simple Random Sampling and Stratified Random Sampling [14L]

Simple Random Sampling: With and Without Replacement, definition and procedure of selecting a Sample, estimates of: population mean, total and proportion, variances of these estimates, estimates of their variances and sample size determination. Applications.

Stratified Random Sampling: Technique, estimates of population mean and total, variances of these estimates, Proportional and Optimum allocations and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision. Applications.

Unit III: Systematic Sampling and Ratio & Regression Methods of Estimation [10L]

Systematic Sampling: Technique, estimates of population mean and total, variances of these estimates ($N = n \times k$). Comparison of Systematic Sampling with SRS and Stratified Sampling in the presence of linear trend and corrections. Circular Systematic Sampling.

Ratio & Regression Methods of Estimation: Introduction, first approximation to the population mean and total (for SRS of large size), MSE of these estimates and estimates of

these variances, MSE in terms of correlation coefficient for Regression method of estimation and their comparison with SRS. Hartley Ross Estimator.

Unit IV: Cluster Sampling and Two-stage Sampling [6L]

Cluster sampling (equal clusters only), estimation of population mean and its variance, comparison (with and without randomly formed clusters). Concept of sub sampling.

Two-stage Sampling, estimation of population mean and variance of the estimate. Comparison between Two-stage, Cluster and Uni-stage Sampling.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2005): Fundamentals of Statistics. Vol. II, 8th Edition. World Press, Kolkata.
2. Murthy M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
3. Cochran W.G. (1984): Sampling Techniques, 3rd Edition, Wiley Eastern.
4. Mukhopadhyay P. (1998): Theory and Methods of Survey Sampling, Prentice Hall.
5. Sukhatme P.V., Sukhatme B.V., Sukhatme S. and Asok C. (1984). Sampling Theory of Surveys With Applications, 3rd Edition (Revised), IOWA State University Press and Indian Society of Agricultural Statistics.
6. Des Raj and Chandhok P. (1998): Sample Survey Theory, Narosa Publishing House.

1090015211	MC13 – Survey Sampling LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Survey Sampling Theory				
Co-requisites	Use of scientific calculators				

Learning objectives:

To provide students the hands-on experience of different statistical methods relating to Survey Sampling along with their real-life applications.

Course learning outcomes:

CO1: **Build** knowledge about solving numerical problems of Simple Random Sampling (SRS).
CO2: **Solve** numerical problems based on Stratified Random Sampling (STRS).
CO3: **Make use of** the knowledge about solving numerical problems related to Linear and Circular Systematic Sampling.
CO4: **Make use of** the knowledge about solving numerical problems related to Ratio & Regression methods of estimation.
CO5: **Apply** the procedures of solving numerical problems related to Cluster Sampling.
CO6: **Solve** numerical problems based on Two-stage Sampling.

Course Content:

List of experiments (to be executed using Scientific Calculators)

Sl. No.	Name of the Experiments
1	To select a SRS With and Without Replacement.
2	For a population of size 5, estimate population mean, population mean square and population variance. Enumerate all possible samples of size 2 by WR and WOR and establish all properties relative to SRS.
3	For SRSWOR, estimate mean, standard error, the sample size.
4	Stratified Random Sampling: allocation of sample to strata by proportional and Neyman's methods. Compare the efficiencies of above two methods relative to SRS.
5	Estimation of gain in precision in Stratified Random Sampling.
6	Comparison of Systematic Sampling with Stratified Random Sampling and SRS in the presence of a linear trend.
7	Ratio and Regression estimation: Calculate the population mean or total of the population. Calculate mean squares.
8	Compare the efficiencies of Ratio and Regression estimators relative to SRS.
9	Cluster Sampling: estimation of mean or total, variance of the estimate.
10	Two-stage Sampling.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2005): Fundamentals of Statistics. Vol. II, 8th Edition. World Press, Kolkata.
2. Murthy M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
3. Cochran W.G. (1984): Sampling Techniques, 3rd Edition, Wiley Eastern.
4. Mukhopadhyay P. (1998): Theory and Methods of Survey Sampling, Prentice Hall.
5. Sukhatme P.V., Sukhatme B.V., Sukhatme S. and Asok C. (1984). Sampling Theory of Surveys With Applications, 3rd Edition (Revised), IOWA State University Press and Indian Society of Agricultural Statistics.
6. Des Raj and Chandhok P. (1998): Sample Survey Theory, Narosa Publishing House.

1090015114	MC14 – Statistical Computing Using R	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Knowledge of Basic Statistics				
Co-requisites	----				

Learning objectives:

- To help students in building knowledge of R environment.
- To help students work with R packages and their uses for given data. R programming with some basic notations for developing their own simple programs and visualizing graphics in R

Course learning outcomes*:*

CO1: **Build** the idea of basic R language, its origin and its application in real world.
CO2: **Illustrate** how to load data and representation of data by using R.
CO3: **Explain** detailed descriptive statistics, correlation, and lines of regression by R.
CO4: **Build** knowledge of random number generation, fitting of curves and applications of real-life problems by using R.
CO5: **Develop** the concepts of regression analysis with their applications by using R.
CO6: **Make use of** the applications of hypothesis testing and p-value by using R.

Course Content:

Unit I: Basics of R and Descriptive Statistics in R **[10L]**

Basic knowledge about R programming, learn how to load data, plot a graph viz. histograms (equal class intervals and unequal class intervals), box plot, stem-leaf, frequency polygon, pie chart, ogives with graphical summaries of data.

Unit II: Correlation and Regression in R **[10L]**

Generate automated reports giving detailed descriptive statistics, correlation and lines of regression.

Unit III: Random number generation and fitting of distributions in R **[8L]**

Random number generation and sampling procedures. Fitting of polynomials and exponential curves. Application Problems based on fitting of suitable distribution, Normal probability plot.

Unit IV: Testing of hypothesis in R **[8L]**

Simple analysis, create, manage statistical analysis, projects, import data, Basics of statistical inference in order to understand hypothesis testing and compute p-values and confidence intervals.

Text & Reference books:

1. Gardener M. (2012): Beginning R: The Statistical Programming Language, Wiley Publications.
2. Braun W. J., Murdoch D. J. (2007): A First Course in Statistical Programming with R. Cambridge University Press. New York
3. A simple introduction to R by Arnab Chakraborty (freely available at http://www.isical.ac.in/~arnabc/)
4. R for beginners by Emmanuel Paradis (freely available at https://cran.r-project.org/doc/contrib/Paradis-rdebuts_en.pdf)

1090015212	MC14 – Statistical Computing Using R LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Statistical Computing Using R Theory				
Co-requisites	Use of Laptop or Computer				

Learning objectives:

To provide students the hands-on experience of R language and using R solving different problem on statistics and make different graph.

Course learning outcomes*:*

***CO1*: Understand** about basic syntax about R.
***CO2:* Understand** about loops, matrices in R.
***CO3:* Apply** the knowledge of R in descriptive statistics to find representation of data, measure of dispersion and central tendency, Skewness and Kurtosis.
***CO4:* Make use of** the knowledge of R in simple and multiple regression, multicollinearity, correlation coefficient and rank correlation coefficients.
***CO5:* Build** the concept of Fitting of curve by linear, quadratic, and higher degree polynomial.
***CO6:* Apply** the knowledge of R to find different types of test and test of normality.

Course Content:

List of experiments (to be executed using R Gui and/or R Studio)

Sl. No.	Name of the Experiments
1	Using R as a calculator.
2	Different Data Types.
3	Different types of Array Operations and Extraction.
4	Use of loops (for, while, repeat), Conditional statements (if, else, if-else).
5	Defining functions in R.
6	Matrices I (Basic matrix operations, Extraction, Use of apply, lapply, sapply functions).
7	Matrices II (Determinant, Inverse, Rank, Eigen value, Eigen Vectors, Solution of Linear Equations).
8	Data representation using R (Diagrams: Bar diagrams, Multiple and Sub-divided Bar diagrams, Line Diagram, Column Diagram, Step Diagram, Histogram, Ogive and Pie-charts).
9	Construction of frequency distribution from raw data (Both grouped and ungrouped Case).
10	Calculation of different descriptive measures (mean, median, mode, quantiles, range, mean deviation about mean and median, standard deviation, variance, g1, g2).
11	Five number data summary and Box Plot.
12	Bivariate data: calculations of correlation coefficient, rank correlation coefficients.
13	Simple and Multiple linear regressions.
14	Fitting of curve by linear, quadratic and higher degree polynomial.
15	Different tests of significance, z-test, t-test, χ^2-test, F-test, ANOVA.
16	Tests of normality (QQ plot, Shapiro-Wilks Test).

Text & Reference books:

1. Gardener M. (2012): Beginning R: The Statistical Programming Language, Wiley Publications.
2. Braun W. J., Murdoch D. J. (2007): A First Course in Statistical Programming with R. Cambridge University Press. New York
3. A simple introduction to R by Arnab Chakraborty (freely available at http://www.isical.ac.in/~arnabc/)
4. R for beginners by Emmanuel Paradis (freely available at https://cran.r-project.org/doc/contrib/Paradis-rdebuts_en.pdf)

Semester VII

1090016115	MC15 – Statistical Inference III	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Probability I, Probability II, Sampling distributions, Statistical Inference I and Statistical Inference II				
Co-requisites	----				

Learning objectives:

Statistical Inference deals with the theory, methods and practice of forming judgements about the parameters of a population and the reliability of statistical relationships, typically on the basis of random sampling. This course will focus on the inferential problems when the structure of the parent distribution is completely unknown or the exact distribution of the statistic is too complicated or unknown. Main objectives of this course are:

- To develop the concepts regarding the process of using data analysis to infer properties of an underlying distribution of probability.
- Students will learn how to make predictions and draw conclusions about a population based on limited information, which is often the case in real-world problems.
- Asymptotic analysis can provide insight into the inference process itself, suggesting what information is available and how this information may be extracted.

Course learning outcomes*:*

CO1: **Build** the knowledge of the Limit Laws in probability theory.
CO2: **Apply** the concepts of WLLN, SLLN and CLT to a statistical inference problem.
CO3: **Make use of** the knowledge of asymptotic inferential techniques when the exact distribution of the statistics are unknown or too complicated to comprehend.
CO4: **Explain** the advantages of Variance Stabilizing Transformations and Pearsonian Chi-square statistic.
CO5: **Apply** the concepts of non-parametric methods when the structure of the parent distribution is unknown.
CO6: **Make use of** the knowledge of different one-sample, two-sample and multi-sample non-parametric problems to solve any real life problem.

Course Content:

UNIT I: Convergence of Random Variables **[8L]**

Sequence of random variables, convergence in probability, convergence in distribution or law, convergence in r^{th} mean, almost sure convergence and their inter-relations. Weak Law of Large Numbers (WLLN) and its applications. Kolmogorov's Strong Law of Large Numbers (SLLN) and its applications. Central Limit Theorem (CLT) and its applications. Slutsky's Theorem and its applications.

UNIT II: Asymptotic Inference **[18L]**

Definition of a consistent estimator and its properties. Sufficient condition for an estimator to be consistent and its uses. Invariance property of a consistent estimator. Concepts of efficiency, more efficient and most efficient estimators. Definition of CAN and BAN estimators.

Delta method, derivation of large sample standard error of sample moments, standard deviation, coefficient of variation, b_1 & b_2 measures and correlation coefficient and their uses in large sample tests and confidence intervals under normality assumption, large sample distribution of sample quantiles. Variance Stabilizing Transformations (VST): derivation and uses of Sin^{-1}, Square root, Logarithmic and z-transformations. Large sample tests for Binomial proportions, Poisson means (single and two independent samples cases) and correlation coefficients. Large Sample distribution of Pearsonian χ^2 statistic and its applications. Yates' correction.

UNIT III: Non Parametric Inference **[10L]**

Nonparametric Tests: Introduction and concept, one sample and two-sample problems, location family and scale family of distributions. Nonparametric tests of single sample and two sample problems: Sign Test, Wilcoxon Signed Rank Test, Mann-Whitney U-Test, Wilcoxon rank sum Test, Wald-Wolfowitz Run test. Concepts of empirical distribution function, Kolmogorov-Smirnov test, Kruskal-Wallis Test.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol. I, The World Press Private Limited, Kolkata.
2. Rohatgi V. K. and Saleh A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edition. (Reprint) John Wiley and Sons, INC.
3. Gun A.M., Gupta M.K. and Dasgupta B.: An Outline of Statistical Theory, Vol. II, The World Press Private Limited, Kolkata.
4. Casella G., Berger RL.: Statistical Inference, Second Edition, Cengage Learning India Private Limited.
5. Kale B.K., Muralidharan K.: Parametric Inference An Introduction, Narosa Publishing House.
6. Mood A.M., Graybill F.A., Boes D.C.: Introduction To The Theory Of Statistics, 3rd Edition, Tata McGraw-Hill Publishing Company Limited.
7. Lehmann E.L.: Elements of Large-Sample Theory, Springer.
8. Jiming Jiang: Large Sample Techniques for Statistics, Springer.
9. Gibbons J.D., Chakraborti S.: Nonparametric Statistical Inference, Marcel Dekker, Inc.

1090016213	MC15 – Statistical Inference III LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Statistical Inference III Theory				
Co-requisites	Use of scientific calculators and Use of different Statistical Tables				

Learning objectives:

To provide the students the hands-on experience of the different aspects of explanatory data analysis by applying the different inferential techniques on real life data sets and comparing them.

Course learning outcomes*:*

CO1: **Make use of** the knowledge of the Delta-method and Central Limit Theorem to find large sample tests and confidence intervals.
CO2: **Apply** the concepts of Variance Stabilizing Transformations to find large sample tests and confidence intervals.
CO3: **Explain** the concepts of Pearsonian Chi-Square statistic.
CO4: **Make use of** the knowledge of Pearsonian Chi-Square statistic in various real life data analysis problems.
CO5: **Solve** practical problems based on single sample non-parametric problems.
CO6: **Solve** practical problems related to two-sample and multi-sample non-parametric problems.

Course Content:

List of experiments (to be executed using Scientific Calculators & Statistical Tables)

Sl. No.	Name of the Experiments
1	Problems based on large sample tests and confidence intervals using large sample distributions.
2	Problems based on large sample tests and confidence intervals using Variance Stabilizing Transformations.
3	Problems based on the applications of Pearsonian Chi-Square statistic.
4	Problems on single sample non-parametric problems.
5	Problems on two-sample non-parametric problems.
6	Problems on multi-sample non-parametric problems.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol. I, The World Press Private Limited, Kolkata.
2. Rohatgi V. K. and Saleh A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edition. (Reprint) John Wiley and Sons, INC.
3. Gun A.M., Gupta M.K. and Dasgupta B.: An Outline of Statistical Theory, Vol. II, The World Press Private Limited, Kolkata.

4. Casella G., Berger RL.: Statistical Inference, Second Edition, Cengage Learning India Private Limited.
5. Kale B.K., Muralidharan K.: Parametric Inference An Introduction, Narosa Publishing House.
6. Mood A.M., Graybill F.A., Boes D.C.: Introduction To The Theory Of Statistics, 3rd Edition, Tata McGraw-Hill Publishing Company Limited.
7. Lehmann E.L.: Elements of Large-Sample Theory, Springer.
8. Jiming Jiang: Large Sample Techniques for Statistics, Springer.
9. Gibbons J.D., Chakraborti S.: Nonparametric Statistical Inference, Marcel Dekker, Inc.

1090016116	MC16 – Regression Analysis	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Statistical Inference I and Linear Models				
Co-requisites	----				

Learning objectives:

To provide students the basic concepts of Regression Analysis and its applications in real-life scenarios.

Course learning outcomes*:*

***CO1*: Define** the underlying concept of Regression Analysis.
***CO2:* Classify** the problem of Regression Analysis.
***CO3:* Apply** various concept of Regression analysis in practical field.
***CO4:* Explain** how a regression model depart from Gauss-Markov setup.
***CO5:* Analyze** the different problems associated with Regression Model.
***CO6:* Interpret** the various results associated with Regression Analysis.

Course Content:

Unit I: Introduction **[6L]**

What is Regression Analysis? Selected applications of Regression Analysis. Steps in Regression Analysis. Covariance and Correlation Coefficient. Simple Linear Regression Model, Multiple Linear Regression Model. Properties of Least Square Estimators, Tests of Hypotheses in a Linear Model.

Unit II: Regression diagnostics and detection of model violations **[12L]**

The Standard Regression Model, various types of residuals, graphical methods, test of fitness of a model, residuals and their plots, detection of outliers, influential observations, leverage, measures of influences, Cook's distance, Welsch and Kuh measure, Hadis's influence measure.

Unit III: Departures from Gauss-Markov setup **[12L]**

Heteroscedasticity, Autocorrelation and Multicollinearity: consequences, detection and remedies. Checking for Normality: Q-Q plots, Normal Probability plot, Shapiro-Wilks test.

Unit IV: **Working with Collinear Data** **[6L]**

Introduction, Principle Components, reduction of Collinearity in estimation data. An introduction of Regression analysis with correlated errors.

Text & Reference books:

1. Scheffe H.: Analysis of Variance
2. Searle S. R.: Linear Models

3. Giri N. C.: Analysis of Variance
4. Cook R. D. & Weisberg S.: Residual and its Influence in Regression
5. Draper N. R. & Smith H.: Applied Regression Analysis
6. Chatterjee S. & Hadi A. S.: Regression Analysis by Example
7. Johnston J.: Econometric Methods
8. Gujrati D.: Basic Econometrics

1090016214	MC16 – Regression Analysis LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Regression Analysis Theory				
Co-requisites	Use of scientific calculators and Knowledge of R Programming				

Learning objectives:

To provide students the hands-on experience of different statistical methods relating to the Regression Analysis problems.

Course learning outcomes*:*

***CO1*: Understand** the problem of Regression Analysis using statistical tools.
***CO2:* Solve** the problems of Simple and Multiple Linear Regressions.
***CO3:* Solve** the problems of Heteroscedasticity, outliers, various types of residuals.
***CO4:* Solve** the problems of Autocorrelation and Multicollinearity.
***CO5:* Apply** various concept of Regression analysis in practical problems.
***CO6:* Interpret** the various results associated with Regression Analysis.

Course Content:

List of experiments (to be executed using Scientific Calculators and/or R Programming)

Sl. No.	Name of the Experiments
1	Problems based on the basic concepts of Regression.
2	Problems based on Simple Linear Regression.
3	Problems based on Multiple Linear Regression.
4	Problems based on standard Regression model.
5	Problems based on various types of residuals.
6	Problems based on graphical methods for detection of outliers.
7	Problems based on measures of influential observations.
8	Problems based on Heteroscedasticity
9	Problems based on Autocorrelation.
10	Problems based on Multicollinearity.

Text & Reference books:

1. Scheffe H.: Analysis of Variance
2. Searle S. R.: Linear Models
3. Giri N. C.: Analysis of Variance
4. Cook R. D. & Weisberg S.: Residual and its Influence in Regression
5. Draper N. R. & Smith H.: Applied Regression Analysis
6. Chatterjee S. & Hadi A. S.: Regression Analysis by Example
7. Johnston J.: Econometric Methods
8. Gujrati D.: Basic Econometrics

1090016117	MC17– Statistical Quality Control	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Basic knowledge of Applied Statistics				
Co-requisites	----				

Learning objectives:

To provide students with an exposure to the basic concepts of Statistical Quality Control and its applications in various industries.

Course learning outcomes:

CO1: **Define** the underlying concepts of Statistical Quality Control.
CO2: **Classify** the problems of process control and product control.
CO3: **Apply** various variable and attribute control charts to comment on the state of control of a given production process.
CO4: **Analyze** the outcomes of using various charts and curves.
CO5: **Make use of** the knowledge of single and double sampling inspection plans for attributes.
CO6: **Explain** the concepts of Six-Sigma and ISO quality standards.

Course Content:

Unit I: Definition and idea of Quality **[6L]**

Definition and dimensions of quality, historical perspective of quality control and improvements starting from World War II, historical perspective of Quality Gurus and Quality Hall of Fame. Quality system and standards: Introduction to ISO quality standards, Quality registration. Difference between Product Control and Process Control. Statistical Process Control - seven tools of SPC, chance and assignable causes of quality variation.

Unit II: Process Control **[12L]**

Statistical Control Charts: construction and statistical basis of 3-σ control charts, Rational Sub-grouping. Control charts for variables: X-bar & R-chart, X-bar & s-chart. Control charts for attributes: np-chart, p-chart, c-chart and u-chart. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on control chart.

Unit III: Product Control **[12L]**

Definitions related to Product Control, Acceptance Sampling Plan, principle of Acceptance Sampling Plans, Single Sampling Plan: its OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, Double Sampling Plan: its OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Romig Sampling Inspection Plan tables.

Unit IV: Process Capability Index and Six-Sigma **[6L]**

Process capability study, index of process capability: Cp, Cpk and Cpmk and their uses. Estimation of process capability indices, Introduction to and overview of Six-Sigma.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2005): Fundamentals of Statistics. Vol. II, 8th Edition. World Press, Kolkata.
2. Montogomery D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.
3. Mukhopadhyay P. (2011): Applied Statistics, 2nd Edition revised reprint, Books and Allied (P) Ltd.
4. Hoyle David (1995): ISO Quality Systems Handbook, 2nd Edition, Butterworth Heinemann Publication.
5. Montogomery D. C. and Runger G.C. (2008): Applied Statistics and Probability for Engineers, 3rd Edition reprint, Wiley India Pvt. Ltd.
6. Ehrlich, B. Harris (2002): Transactional Six Sigma and Lean Servicing, 2nd Edition, St. Lucie Press.

1090016215	MC17– Statistical Quality Control LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Statistical Quality Control Theory				
Co-requisites	Use of scientific calculators				

Learning objectives:

To provide students with an exposure to the applications of Variable and Attribute Control Charts, construction and interpretation of OC, AQL, LTPD, ASN, AOQ and AOQL curves and calculation of Process Capability.

Course learning outcomes:

CO1: **Identify** the problems based on different control charts.
CO2: **Explain** the theoretical basis of the given statistical quality control problem.
CO3**: Compare** the different control charts, 3-sigma control limits with specification limits.
CO4**: Solve** the given problem as per data and requirement.
CO5**: Design** sampling inspection plan for a given problem.
CO6: **Construct** OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves.

Course Content:

List of experiments (to be executed using Scientific Calculators)

Sl. No.	Name of the Experiments
1	Problems based on construction and interpretation of Statistical Control Charts: X-bar & R-chart.
2	Problems based on construction and interpretation of Statistical Control Charts: X-bar & s-chart.
3	Problems based on construction and interpretation of Statistical Control Charts: np-chart.
4	Problems based on construction and interpretation of Statistical Control Charts: p-chart.
5	Problems based on construction and interpretation of Statistical Control Charts: c-chart.
6	Problems based on construction and interpretation of Statistical Control Charts: u-chart.
7	Problems based on Single Sample Inspection Plan: construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves.
8	Problems based on Double Sample Inspection Plan: construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves.
9	Problems based on calculation of process capability.
10	Problems based on comparison of 3-sigma control limits with specification limits.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2005): Fundamentals of Statistics. Vol. II, 8th Edition. World Press, Kolkata.
2. Montogomery D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.
3. Mukhopadhyay P. (2011): Applied Statistics, 2nd Edition revised reprint, Books and Allied (P) Ltd.
4. Hoyle David (1995): ISO Quality Systems Handbook, 2nd Edition, Butterworth Heinemann Publication.
5. Montogomery D. C. and Runger G.C. (2008): Applied Statistics and Probability for Engineers, 3rd Edition reprint, Wiley India Pvt. Ltd.
6. Ehrlich, B. Harris (2002): Transactional Six Sigma and Lean Servicing, 2nd Edition, St. Lucie Press.

Semester VIII

1090017118	MC18 – Multivariate Analysis	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Probability I, Probability II, Descriptive Statistics II, Linear Algebra				
Co-requisites	----				

Learning objectives:

Multivariate Analysis involves evaluating multiple variables to identify any possible association among them. It offers a more complete examination of data by looking at all possible independent variables and their relationships to one another. In a broad sense it is the set of statistical methods aimed simultaneously analyze datasets. The main objectives of this course are:

- To find patterns and correlations between several variables simultaneously.
- Useful for analyzing complex datasets, allowing to gain deeper understanding of the data and how it relates to real-world scenarios.
- It has a huge application in Pattern Recognition and Dimension Reduction.

Course learning outcomes*:*

CO1: **Build** the knowledge of multivariate probability distributions to summarize a number of approaches to multivariate probability modelling.
CO2: **Make use** of the knowledge of multiple regression to measure the dependence between correlated random variables.
CO3: **Apply** the concepts of the multiple correlation to measure the efficacy of a multiple linear regression model and partial correlation coefficients to judge the significance of a random variable in a multiple linear regression model.
CO4: **Explain** different aspects of multivariate normal and multinomial distributions to model real-life complex datasets.
CO5: **Develop** knowledge about the basic concepts and associated results of principal component analysis.
CO6: **Demonstrate** the basic ideas of factor analysis as a dimension reduction technique.

Course Content:

UNIT I: Multivariate Probability Distribution [6L]

Definition of random vectors, probability distribution over multi-dimensional Euclidean space, joint CDF of a random vector and its properties, discrete and continuous random vectors, joint PMF and PDFs and their properties, relationship between joint and marginal distributions, conditional distributions and statistical independence. Mean vector and variance-covariance/dispersion matrix of a random vector, properties of dispersion matrix and associated results.

UNIT II: Multiple Regression **[12L]**

Multiple regression related to multi-dimensional random vectors and associated results. Multiple linear regression model involving dependent random variables, expressions of the regression coefficients, error involved in a multiple linear regression model and its properties. Multiple correlation and partial correlation coefficients, their significance and associated results.

UNIT III: Different Multivariate Probability distributions and Tests **[6L]**

Multinomial distribution & Multivariate normal distributions and their properties. Tests for Multiple and Partial correlation coefficients.

UNIT IV: Dimension Reduction Techniques **[12L]**

Principal Component Analysis: introduction, objectives, geometrical significance, population principal components and associated results, principal components for standardized variables, Scree plot, summarizing sample variation by principal components.

Factor Analysis: introduction, Orthogonal Factor Model along with its assumptions, concepts of common factors, specific factors, factor loadings and loading matrix, communality, specific variance. Methods of estimation: Principal Component method. Concept of Factor Rotation - Varimax Rotation.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol. I, The World Press Private Limited, Kolkata.
2. Gun A.M., Gupta M.K. and Dasgupta B.: An Outline of Statistical Theory, Vol. I, The World Press Private Limited, Kolkata.
3. Gun A.M., Gupta M.K. and Dasgupta B.: An Outline of Statistical Theory, Vol. II, The World Press Private Limited, Kolkata.
4. Anderson T.W.: An Introduction to Multivariate Statistical Analysis, 3rd Edition, John Wiley & Sons, Inc.
5. Johnson R.A. and Wichern D.W.: Applied Multivariate Statistical Analysis, 6th Edition., Pearson Education, Inc.
6. Kshirsagar A.M. (1972): Multivariate Analysis, 1st Edition, Marcel Dekker.

1090017216	MC18 – Multivariate Analysis LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Multivariate Analysis Theory				
Co-requisites	Use of scientific calculators and/or R Programming				

Learning objectives:

To provide the students the hands-on experience of the different applications of multivariate analysis like determination of relationships and analyze patterns among large sets of data.

Course learning outcomes*:*

CO1: **Make use of** the knowledge of random vectors and multivariate probability distributions in modelling real life datasets.
CO2: **Apply** the concepts of multiple linear regression.
CO3: **Make use of** the knowledge of multiple and partial correlation coefficients in determining the model efficacy.
CO4: **Solve** practical problems based on the multinomial and multivariate normal distribution.
CO5: **Solve** numerical problems based on principal component analysis.
CO6: **Solve** numerical problems based on factor analysis.

Course Content:

List of experiments (to be executed using Scientific Calculators and/or R Programming)

Sl. No.	Name of the Experiments
1	Problems based on the multivariate probability distributions.
2	Problems based on the multiple linear regression.
3	Problems based on the multinomial distribution.
4	Problems based on multivariate normal distribution.
5	Problems based on Principal Component Analysis.
6	Problems based on Factor Analysis.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol. I, The World Press Private Limited, Kolkata.
2. Gun A.M., Gupta M.K. and Dasgupta B.: An Outline of Statistical Theory, Vol. I, The World Press Private Limited, Kolkata.
3. Gun A.M., Gupta M.K. and Dasgupta B.: An Outline of Statistical Theory, Vol. II, The World Press Private Limited, Kolkata.
4. Anderson T.W.: An Introduction to Multivariate Statistical Analysis, 3rd Edition, John Wiley & Sons, Inc.
5. Johnson R.A. and Wichern D.W.: Applied Multivariate Statistical Analysis, 6th Edition., Pearson Education, Inc.
6. Kshirsagar A.M. (1972): Multivariate Analysis, 1st Edition, Marcel Dekker.

1090017119	MC19 – Discrete Data Analysis	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Probability II, Descriptive Statistics II, Statistical Inference I, Linear Models and Regression Analysis				
Co-requisites	----				

Learning objectives:

Categorical data, meaning data that is non-numerical by nature, are often collected in scientific studies. This type of data can be used to show relationship between variables and it is invaluable to collect and compile in studies. Discrete data analysis or categorical data analysis is used to gather information from both online and offline surveys or questionnaires as the case may be. The type of categorical data used may differ depending on the aim of data collection. The main objectives of this course are:

- To develop concepts about how to relate some number of continuous and/or categorical predictors to a single outcome variable.
- To allow for more flexible, non-linear relationships by using a different underlying statistical distribution.
- Categorical data analysis has a huge application in epidemiological studies.

Course learning outcomes*:*

CO1: **Apply** the concepts of different types of categorical data.
CO2: **Make use of** the knowledge of different measures of associations in different aspects of data analysis.
CO3: **Build** the knowledge of the Generalized Linear Models (GLM) to analyze more flexible and non-linear relationships among the variables.
CO4: **Explain** the advantages of log regression and logistic regression.
CO5: **Apply** the concepts of modelling binary data, count data and polytomous data in real-life situations.
CO6: **Make use of** the knowledge of Maximum likelihood and Quasi likelihood methods for the purpose of the data modelling.

Course Content:

UNIT I: Review of Categorical Data **[8L]**

A brief review of categorical data, its classifications. Design of study: Retrospective and Prospective studies, case control study and cohort study. Measures of association.

UNIT II: Generalized Linear Models (GLM) **[16L]**

Introduction, departure from a linear model, components of a GLM, uses of different links: Logit link, Probit link, Log-linear link, Logistic regression, Log regression, Maximum Likelihood Estimation and Deviance.

UNIT III: Different Discrete Data and Models **[12L]**

Binary data and count data: grouped and ungrouped. Models with constant coefficient of

variation. Polytomous data. Overdispersion and fitting by quasi-likelihood. Zero-inflated Poisson models.

Text & Reference books:

1. Agresti A.: Analysis of Ordinal Categorical Data, John Wiley & Sons, Inc.
2. Agresti A.: Categorical Data Analysis, John Wiley & Sons, Inc.
3. McCullagh P., Nelder A.J.: Generalized Linear Models, 2nd Edition, Chapman and Hall.
4. McCulloch C.E., Searle S.R., Neuhaus John M.: Generalized, Linear, and Mixed Models, 2nd Edition, John Wiley & Sons, Inc.
5. Hastie T., Tibshirani R.: Generalized Additive Models, Chapman & Hall/CRC.
6. Annette J. Dobson: An Introduction To Generalized Linear Models, 2nd Edition, Chapman & Hall/CRC.
7. Faraway Julian J.: Linear Models with R, 2nd Edition, CRC Press Taylor & Francis Group.

1090017217	MC19 – Discrete Data Analysis LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Discrete Data Analysis Theory				
Co-requisites	Use of scientific calculators and/or R Programming				

Learning objectives:

To provide the students the hands-on experience of the different applications of Categorical data analysis and Generalized Linear Models in modelling real life data sets.

Course learning outcomes*:*

CO1: **Make use of** the knowledge of the various types of categorical data and find different measures of association for dichotomous data.
CO2: **Apply** the concepts of concordance and discordance to find different measures of association for ordinal vs ordinal data.
CO3: **Make use of** the knowledge of Generalized Linear Models to fit a real life data.
CO4: **Solve** practical problems on Logistic regression.
CO5: **Solve** practical problems on Log-linear regression.
CO6: **Solve** practical problems based on Probit regression.

Course Content:

List of experiments (to be executed using Scientific Calculators and/or R Programming)

Sl. No.	Name of the Experiments
1	Problems based on the measures of association for dichotomous data.
2	Problems based on concordance and discordance and related measures.
3	Problems based on the fitting of Generalized Linear Models.
4	Problems based on Logistic regression.
5	Problems based on Log-linear regression.
6	Problems based on Probit regression.

Text & Reference books:

1. Agresti A.: Analysis of Ordinal Categorical Data, John Wiley & Sons, Inc.
2. Agresti A.: Categorical Data Analysis, John Wiley & Sons, Inc.
3. McCullagh P., Nelder A.J.: Generalized Linear Models, 2nd Edition, Chapman and Hall.
4. McCulloch C.E., Searle S.R., Neuhaus John M.: Generalized, Linear, and Mixed Models, 2nd Edition, John Wiley & Sons, Inc.
5. Hastie T., Tibshirani R.: Generalized Additive Models, Chapman & Hall/CRC.
6. Annette J. Dobson: An Introduction To Generalized Linear Models, 2nd Edition, Chapman & Hall/CRC.
7. Faraway Julian J.: Linear Models with R, 2nd Edition, CRC Press Taylor & Francis Group.

1090017120	MC20 – Demography and Survival Analysis	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Basic knowledge of Applied Statistics and Probability Distributions				
Co-requisites	----				

Learning objectives:

- To introduce the students with the different methodologies of handling data on Demography & Vital Statistics.
- To make the students aware about the statistical procedures related to Survival Analysis and Competing Risk Theory.

Course learning outcomes*:*

***CO1*: Demonstrate** the introductory concepts of vital statistics and measurements of mortality.
***CO2:* Develop** knowledge about the description and construction of life tables.
***CO3:* Explain** the different measures of fertility and population growth.
***CO4:* Build** knowledge about the different survival distributions and their applications.
***CO5:* Outline** the different censoring schemes along with real-life examples.
***CO6:* Explain** the basic concepts of competing risk theory.

Course Content:

Unit I: Introduction to Demography and Measurements of Mortality [8L]

Introduction: sources of data on Vital Statistics, errors in Census and Registration data. Measurement of population, Rates and Ratios of vital events. Measurements of Mortality: Crude Death Rate (CDR), Specific Death Rate (SDR), Standardized Death Rate (STDR), Cause of Death Rate, Case Fatality Rate, Infant Mortality Rate (IMR), Maternal Mortality Rate (MMR), Neonatal and Perinatal Mortality Rates.

Unit II: Life Tables and Measurements of Fertility & Population Growth [10L]

Life (Mortality) Tables: assumption, descriptions of Complete and Abridged Life Tables, Cohort vs. Current Life Tables, Stationary and Stable population, Construction of Complete Life Table from population and death statistics, Central Mortality Rates and Force of Mortality, Uses of Life Tables. Measurements of Fertility: Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR) and Total Fertility Rate (TFR). Measurement of Population Growth: Crude rate of natural increase, Pearl's Vital Index, Gross Reproduction Rate (GRR) and Net Reproduction Rate (NRR).

Unit III: Survival Analysis [12L]

Introduction, Functions of Survival times, Survival distributions and their applications: Exponential, Gamma, Weibull, Rayleigh, Lognormal distributions and distribution having bath-tub shaped hazard function. Mean Residual Time. Censoring Schemes: Type I, Type II and Progressive or Random Censoring with biological examples. Estimation of mean survival time and variance of the estimator for Type I and Type II censored data with numerical

examples. Non-parametric methods: Actuarial and Kaplan-Meier methods for estimating survival function and variance of the estimator.

Unit IV: Competing Risk Theory **[6L]**

Indices for measurement of probability of death under Competing Risks and their interrelations. Estimation of probabilities of death using maximum likelihood principle and modified minimum Chi-square methods.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. II, 8th Edition. The World Press, Kolkata.
2. Mukhopadhyay P. (1999): Applied Statistics, Books and Allied (P) Ltd.
3. Kleinbaum D. J. and Klein M. (2012): Survival Analysis – A Self Learning Text, 3rd Edition. Springer.
4. Klein J. P. and Moeschberger M. L. (2003): Techniques of Censored and Truncated Data, 2nd Edition. Springer.
5. Lee E.T. and Wang J.W. (2003): Statistical Methods for Survival data Analysis, 3rd Edition, John Wiley and Sons.

1090017218	MC20 – Demography and Survival Analysis LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Demography and Survival Analysis Theory				
Co-requisites	Use of scientific calculators and/or Microsoft Excel				

Learning objectives:

- To provide students the hands-on experience of different statistical methods relating to Demography along with their real-life applications.
- To provide students the hands-on experience of different statistical procedures relating to Survival Analysis along with their real-life applications.

Course learning outcomes*:*

***CO1*: Make use of** the knowledge of solving numerical problems relating to different mortality rates.
***CO2:* Propose** solutions relating to numerical problems based on construction of life tables.
***CO3:* Demonstrate** the calculation procedures relating to the measurement of fertility and population growth.
***CO4:* Estimate** the survival function, death density function and hazard function corresponding to different survival distributions.
***CO5:* Evaluate** the mean survival time and variance of the estimator for different censoring schemes.
***CO6:* Solve** numerical problems based on the estimation of survival function and variance of the estimator using non-parametric methodologies.

Course Content:

List of experiments (to be executed using Scientific Calculators and/or MS Excel)

Sl. No.	Name of the Experiments
1	To calculate Crude Death Rate (CDR) and Age Specific Death Rate (ASDR) for a given set of data.
2	To calculate Standardized Death Rate (STDR) by: a. Direct method b. Indirect method.
3	To construct a Complete Life Table.
4	To fill in the missing entries in a Life Table.
5	To calculate Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR) and Total Fertility Rate (TFR) for a given set of data.
6	To calculate Crude rate of Natural Increase (CRNI) and Pearle's Vital Index (VI) for a given set of data.
7	To calculate Gross Reproduction Rate (GRR) and Net Reproduction Rate (NRR) for a given set of data and compare them.
8	To estimate survival function.

9	To determine death density function and hazard function.
10	To identify type of censoring and to estimate survival time for type I censored data.
11	To identify type of censoring and to estimate survival time for type II censored data.
12	To identify type of censoring and to estimate survival time for progressively type I censored data.
13	Estimation of mean survival time and variance of the estimator for type I censored data.
14	Estimation of mean survival time and variance of the estimator for type II censored data.
15	Estimation of mean survival time and variance of the estimator for progressively type I censored data.
16	To estimate the survival function and variance of the estimator using Non-parametric methods with Actuarial methods.
17	To estimate the survival function and variance of the estimator using Non-parametric methods with Kaplan-Meier method.

Text & Reference books:

1. Gun A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. II, 8th Edition. The World Press, Kolkata.
2. Mukhopadhyay P. (1999): Applied Statistics, Books and Allied (P) Ltd.
3. Kleinbaum D. J. and Klein M. (2012): Survival Analysis – A Self Learning Text, 3rd Edition. Springer.
4. Klein J. P. and Moeschberger M. L. (2003): Techniques of Censored and Truncated Data, 2nd Edition. Springer.
5. Lee E.T. and Wang J.W. (2003): Statistical Methods for Survival data Analysis, 3rd Edition, John Wiley and Sons.

1090017121	MC21 – Operations Research	C	L	T	P
Version 1.0	**Contact Hours – 36**	3	3	0	0
Pre-requisites/Exposure	Basic Mathematics				
Co-requisites	----				

Learning objectives:

To introduce the students with the basic concepts of Linear Programming Problem and Operations Research.

Course learning outcomes*:*

***CO1*: Define** the underlying concept of Operations Research.
***CO2:* Classify** the problems of Linear Programming.
***CO3:* Apply** the concept of Game theory in practical life.
***CO4:* Analyze** the various inventory models.
***CO5:* Explain** the concepts of Queuing theory in our daily life.
***CO6:* Interpret** the various results associated with Operations Research.

Course Content:

UNIT I: Introduction **[2L]**

Definition and scope of Operations Research, models and their solutions, decision making under certainty, uncertainty, risk and competition.

UNIT II: Linear Programming Problem **[15L]**

Linear Programming Problem, Duality, Transportation problem, Assignment Problem, Travelling salesman Problem.

UNIT III: Game Theory **[4L]**

Games in normal form, pure and mixed strategies, solution of 2×2, $m \times 2$, $2 \times n$ and $m \times n$ zero sum games by dominance principles and graphical method, LP formulation of matrix games, fundamental theorem of matrix game.

UNIT IV: Inventory Control **[8L]**

Analytical structure of inventory problems, EOQ formula of Harris and Wilson and its sensitivity analysis, extension of EOQ formula allowing quantity discounts and shortages, models with random demand, static risk models, ABC analysis.

UNIT V: Queuing Theory **[7L]**

Queuing models-specifications and effectiveness measure, M/M/1and M/M/C queues and their steady state solutions, waiting time distribution for M/M/1 queue.

Text & Reference books:

1. Taha H. (1995): Operations Research: An Introduction, Prentice- Hall India.
2. Phillips D. T., Ravindran A. and Solberg J.: Operations Research: Principle and Practice
3. Gross C. and Harris C. M.: Fundamentals of Queuing Theory
4. Swarup K., Gupta P.K. and Mohan M (2010): Operations Research, Sultan Chand & Sons.

1090017219	MC21 – Operations Research LAB	C	L	T	P
Version 1.0	**Contact Hours – 24**	1	0	0	2
Pre-requisites/Exposure	Operations Research Theory				
Co-requisites	----				

Learning objectives:

To provide students the hands-on experience of different mathematical and statistical methods relating to Operations Research.

Course learning outcomes*:*

***CO1*: Understand** the problem of Operations Research using statistical tools.
***CO2:* Solve** the problems related to simplex and dual simplex.
CO3:.**Solve** the problems related to transportation and assignment.
***CO4*: Solve** the problems related to various inventory control models.
***CO5:* Apply** various concept of queuing theory problems in practical fields.
***CO6:* Interpret** the various results associated with Operations Research.

Course Content:

List of experiments (to be executed using Scientific Calculators)

Sl. No.	Name of the Experiments
1	Problems based on basic concept of Operations Research.
2	Problems based on linear programming problem.
3	Problems based on graphical method.
4	Problems based on Simplex method.
5	Problems on Dual Simplex method.
6	Problems based on Big M method.
7	Problems related to Two Phase method.
8	Problems based on Transportation method
9	Problems based on Assignment method.
10	Problems based on various Inventory models.
11	Problems based on various Queuing models.
12	Problems based on Game Theory.

Text & Reference books:

1. Taha H. (1995): Operations Research: An Introduction, Prentice- Hall India.
2. Phillips D. T., Ravindran A. and Solberg J.: Operations Research: Principle and Practice
3. Gross C. and Harris C. M.: Fundamentals of Queuing Theory
4. Swarup K., Gupta P.K. and Mohan M (2010): Operations Research, Sultan Chand & Sons.
