Central University of Rajasthan
Department of Statistics

3-Year B. Sc. Statistics

4-Year B.Sc. (Hons with Research) Statistics

5-year M.Sc. Statistics

Proposed to be implemented for the students admitted in academic year 2026 and onwards

and also for the students admitted in B.Sc. Statistics Programme started in 2024-25 and 2025-26

Department of Statistics

School of Mathematics Statistics and Computational Sciences

Central University of Rajasthan

Bandarsindri, NH-8, Kishangarh, Ajmer, Rajasthan

305801

Department of Statistics
Central University of Rajasthan
Structure of the 4 year UG Program

The NEP 2020 based Four-Year UG Programme is an 8-semester (4-year) program with multiple exit and entry options at the successful completion of courses assigned at the end of each year.

- Students who opt to exit after completion of the first year and have secured 40 credits will be awarded a UG certificate if, in addition, they complete one vocational course of 4 credits during the summer vacation of the first year. These students are allowed to re-enter in the degree program any time and complete the diploma/degree program within the maximum period of eight years from the initial registration year.

- Students who opt to exit after completion of the second year and have secured 80 credits will be awarded the UG diploma if, in addition, they complete one vocational course of 4 credits during the summer vacation of the second year. These students are allowed to re-enter in the degree program any time and complete the degree program within the maximum period of eight years from the initial registration year.

- Students who wish to undergo a 3-year UG program will be awarded UG degree in the Major discipline after successful completion of three years securing 120 credits. These students are allowed to re-enter in the honors program any time and complete the same program within the maximum period of eight years from the initial registration year.

- Students who wish to undergo a 4-year UG program will be awarded Honors degree in the major discipline after successful completion of four years degree program with 160 credits.

- Student who meet minimum requirement of CGPA of 7.5, shall be eligible for an Honors with Research degree in respective discipline/field of study after successful completion of 160 Credit, including 12 Credits from a research project.

Learning outcome of this program,

Graduates of the 3-Year B. Sc./ 4-Year B.Sc. (Hons with Research) Statistics program will be able to:

PO1: Disciplinary Knowledge

Graduates will demonstrate a broad and integrated understanding of Statistics and its interrelated sub-disciplines, with in-depth knowledge in selected areas.

PO2: Statistical Reasoning & Problem Solving

Graduates will apply principles of probability and statistics to model random phenomena and solve real-world problems using appropriate analytical techniques.

PO3: Data Collection, Experimentation & Inference

Graduates will design sampling methods and experiments, analyze data, and draw valid statistical inferences to support evidence-based decision-making.

PO4: Scholarly Literacy & Lifelong Learning

Graduates will independently read, interpret, and critically evaluate statistical literature and online resources for continuous learning and professional growth.

PO5: Professional Competence & Career Readiness

Graduates will be prepared to work effectively in industry, research, government, healthcare, education, and analytics sectors, or pursue higher studies in statistics and related fields.

Structure of the Under-Graduate Program:

Minimum Credit requirements to Award Certificate/ Diploma/ Degree under each category

Minimum Credit Requirement					
S. No.	**Course Category**	**UG certificate (1-year)**	**UG diploma (2-year)**	**BSc degree (3-year)**	**BSc Honors/Honors with Research (4-year)**
1	Major	8	30	64	82
2	Minor	8	16	24	32
3	IDC	6	9	9	9
4	AEC	4	8	8	8
5	SEC	6	9	9	9
6	VAC	8	8	8	8
7	Summer Internship	--	--	--	--
8	Research Project / Dissertation	--	--	--	12
	Total	**40+4***	**80+4***	**120**	**160**

A student opting for exit after first year will be awarded UG Certificate, if, in addition to 40C, s/he completes one vocational course of 4C during summer.
A student opting for exit after second year will be awarded UG Diploma, if, in addition to 80C, s/he completes one vocational course of 4C during summer.
Honors students will do courses for 12 Credits in lieu of a research project

Major: Course in major discipline	**Minor:** Course in minor discipline
IDC: Inter-Disciplinary Course	**AEC:** Ability Enhancement Course
SEC: Skill Enhancement Course	**VAC:** Value Added Course
The courses under minor discipline can be opted by the students from other departments of the University or from MOOC offered by SWAYAM/NPTEL/any other recommended plateform.	

Eligibility for lateral Entries

S.No.	Lateral Entry to	Eligibility
1	First Semester: UG programme	Student should have 10 + 2 in Science Stream or equivalent of any recognized board in India with Mathematics as one of the optional subjects having 50% marks or equivalent grade in aggregate for general category and 45% or equivalent grade for SC/ST/OBC/PWD/EWS candidates.
2	Third Semester (after Certificate)	Student should have 10+2 with Mathematics as one of the subject and **Completed 2 core/major/minor courses in Statistics (excluding practical)** in first two semester of their UG Certificate.
3	Fifth Semester (after Diploma)	Student should have 10+2 with Mathematics as one of the subject and **completed at least 4 core/major/minor in Statistics (excluding practical)** in first four semester of their UG Diploma.
4	Seventh Semester (after Degree) for Honors / Research	Student should have Bachelor degree in Statistics/ Applied Statistics/Computational Statistics
5	Ninth Semester for M.Sc. Segree	Students should have B.Sc. (Hons / Research) in Statistics.

Number of courses (with Credits) under each category of courses:

S.No.	Semester	Major	Minor	IDC	AEC	SEC	VAC	Summer Internship	Research Project
1	I	1 (4C)	1 (4C)	1 (3C)	1 (2C)	1 (3C)	1 (4C)	--	--
2	II	1 (4C)	1 (4C)	1 (3C)	1 (2C)	1 (3C)	1 (4C)	--	--
3	III	2 (8C)	1 (4C)	1 (3C)	1 (2C)	1 (3C)		--	-
4	IV	4 (14C)	1 (4C)	--	1 (2C)	--		--	-
5	V	5 (16C)	1 (4C)	--	--	--		--	-
6	VI	4 (16C)	1 (4C)	--	--	--		--	-
7	VII	3 (12C)	2 (8C)	--	--	--		--	-
8	VIII	2 (8C)	--	--	--	--		--	1(12 C)
	Total	**82**	**32**	**9**	**8**	**9**	**8**		**12**

* Project of 12 Credits in place of courses for the 4-year UG Honours with Research degree progamme

CORE: MAJOR AND MINOR
M/IDC: MULTI/ INTERDISCIPLINARY COURSES
AEC: ABILITY ENHANCEMENT COURSES (LANGUAGE)
SEC: SKILL ENHANCEMENT COURSES
INT: INTERNSHIP
DISS: DISSERTATION
VAC: COMMON VALUE-ADDED COURSES

Semester I					
S.No.	**Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1	STA 111	4.5STA01	Descriptive Statistics	Major 1	4
2			Course offered from Math/EVS/CS/Eco/Linguistics /other departments	Minor 1	4
3	STA 141	4.5STA41	Data Visualization and Interpretation	IDC 1	3
4	STA 151	4.5STA51	Data Analysis using Excel	SEC 1	3
5			Language and Communication Skill I	AEC 1	2
6			YOGA/ SOCIAL WORK/Other course offered by University	VAC 1	4
					Total Credits = 20

Semester II					
S.No.	**Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1	STA 112	4.5STA02	Probability and Random Variables	Major 2	4
2			(Math/EVS/CS/Eco/Linguistics / other departments)	Minor 2	4
3	STA 142	4.5STA42	Course offered from Math/ EVS/CS/Eco/Stats/Linguistics/other departments	IDC 2	3
4	STA 152	4.5STA52	Introduction to R	SEC 2	3
5			Language and Communication Skill II	AEC 2	2
6			YOGA/ SOCIAL WORK/ HUMAN VALUES/ Other course offered by University	VAC 2	4
					Total Credits = 20

A student opting for exit after first year (2 semesters) will be awarded '**UG Certificate in Statistics**' if in addition to 40 Credits, they complete one vocational course of 4 Credits.

Semester III					
S.No.	**Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1	STA 211	5.0STA01	Probability Distributions-I	Major 3	4
2	STA 212	5.0STA02	Statistical Methods	Major 4	4
3			Course offered from Math/Physics/EVS/CS/Eco/Stats/ Linguistics/other departments	Minor 3	4
4	STA 241	5.0STA41	From other Math/Physics/EVS/CS/Eco/Stats/Linguistics/other departments	IDC 3	3
5	STA 251	5.0STA51	Fundamental of Data Collection and Analysis	SEC 3	3
6	STA 261	5.0STA61	Statistical Computing–I	AEC 3	2
					Total Credits = 20

Semester IV					
S.No.	**Course Code**	**Revised code**	**Title of Courses**	**Type of Course**	**Credits**
1	STA 213	5.0STA03	Probability Distributions -II	Major 5	4
2	STA 214	5.0STA04	Applied Statistics	Major 6	4
3	STA 215	5.0STA05	Statistical Inference - I	Major 7	4
4			MOOC Course	Major 8	2
5			From course from other Departments	Minor 4	4
6	STA 262	5.0STA62	Statistical Computing –II	AEC 4	2
					Total Credits = 20
A student opting for exit after two years (4 semesters) will be awarded '**UG Diploma in Statistics**' if in addition to 80 Credits, they complete one vocational course of 4 Credits.					

Semester V					
S.No.	**Course Code**	**Revised code**	**Title of Courses**	**Type of Course**	**Credits**
1	STA 311	5.5STA01	Design of Experiments	Major 9	4
2	STA 312	5.5STA02	Statistical Quality Control and Operations Research	Major 10	4
3	STA 313	5.5STA03	Sample Survey	Major 11	4
4	STA 314	5.5STA04	Practicals (Based on Core STA 311- STA 313 / 5.5.STA01-5.5STA03)	Major 12	2
5		**5.5STA09**	**Foundations and Growth of Statistics in India**	**IKS**	**2**
6			MOOC Course / Course offered from other Departments	Minor 5	4
					Total Credits = 20

Semester VI					
S.No.	**Course Code**	Revised Code	**Title of Courses**	**Type of Course**	**Credits**
1	STA 315	5.5STA05	Time Series Analysis & Forecasting	Major 13	4
2	STA 316	5.5STA06	Statistical Inference-II	Major 14	4
3	STA 317	5.5STA07	Reliability and Survival Analysis	Major 15	4
4	STA 318	5.5STA08	Practicals (Based on STA 315 - STA 317/5.5.STA05-5.5STA07)	Major 16	4
5			Course offered from Other Department/ MOOCS course	Minor 6	4
					Total Credits = 20
A student opting for exit after three years (6 semesters) will be awarded 'B.Sc. in Statistics' degree.					

Semester VII					
S.No.	**Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1	STA 411	6.0STA01	Probability Theory	Major 17	4
2	STA 412	6.0STA02	Distribution Theory	Major 18	4
3	STA 413	6.0STA03	Sampling Theory	Major 19	4
4			Course from department/ another department/ MOOC	Minor 7	3
5			Course from department/ another department/elective / MOOC	Minor 8	3
6	-	6.0STA61	Professional Communication	AEC	2
					Total Credits = 20

Semester VIII (B.Sc. Hons with Research)*					
S.No.	**Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1	STA 416	6.0STA06	Theory of Estimation and Testing of Hypothesis	Major 20	4
2	STA 417	6.0STA07	Regression Analysis	Major 21	4
3	STA 432	6.0STA82	Project	Research Project	12
					Total Credits = 20

*A student can opt for a project if they secure a minimum of 75% marks in first six semesters of B.Sc. and they will be awarded 'B.Sc. (Hons with Research)' degree.

Semester VIII (B.Sc. Hons)**					
S.No.	**Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1	STA 416	6.0STA06	Theory of Estimation and Testing of Hypothesis	Major	4
2	STA 417	6.0STA07	Regression Analysis	Major	4
3	STA 418	6.0STA08	Stochastic Processes	Major	4
4.	STA 419	6.0STA09	Design and Analysis of Experiments	Major	3
5.			DSE : From list of electives	DSE/ACE/MOOCS	3
6.	STA 431	6.0STA81	Minor Project	RP	2
					Total Credits = 20

A student not opting for a project will have to take elective courses of 12 credits and they will be awarded 'B.Sc. (Hons) in Statistics**' degree.

Semester IX					
S.No.	**Course Code**	Revised Code	**Title of Courses**	**Type of Course**	**Credits**
1.	STA 511	6.5STA01	Multivariate Time Series Analysis and Forecasting	CORE	4
2.	STA 512	6.5STA02	Multivariate Analysis	CORE	4
3.	STA 513	6.5STA03	Survival Analysis	CORE	4
4.	STA		DSE	DSE	3
5.	STA		DSE	DSE	3
6	STA 561	6.5STA61	Seminar / Summer Internship presentation	AEC	2
					Total Credits = 20
Semester X					
S.No.		Revised Code	**Title of Courses**	**Type of Course**	**Credits**
1.	STA 531	6.5STA81	Major Research Project (in Industry or in Academia)	RP	20
					Total Credits = 20
A student will be awarded 'M.Sc. in Statistics' degree if he complete minimum 80 credits of courses in two year of duration of their M.Sc. Degree.					

Major: (code lie in 01-30)
GE/DSE: Generic Elective/ Discipline Specific Elective (code lies in 31-40)
IDC: Inter-Disciplinary Course (code lies in 41-49)
SEC: Skill Enhancement Course (code lies in 51-59)
AEC: Ability Enhancement Course (code lies in 61-69)
RP: Research Project (code lies in 81-85)

List of Electives

Semester VIII					
S.No.	**Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1.	STA 481	6.0STA31	National Development Statistics	DSE	3
2.	STA 482	6.0STA32	Computer Intensive Statistical Methods	DSE	3
3.	STA 484	6.0STA33	Machine Learning	DSE	3
Semester IX					
S.No.	**Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1.	STA 581	6.5STA31	Econometrics.	DSE	3
2.	STA 582	6.5STA32	Discrete Data Analysis	DSE	3
3.	STA 583	6.5STA33	Nonparametric Statistics	DSE	3
4.	STA 584	6.5STA34	Tools for Data Science	DSE	3
5.	STA 585	6.5STA35	Bayesian Inference	DSE	3
6	STA 586	6.5STA36	Optimization Techniques	DSE	3

Course Name: Descriptive Statistics		**Course Code: STA 111/4.5STA01**
Teaching Scheme	**Examination Scheme**	**Credit : 4**
Theory: 4 hrs/ week	ESE: 60 Marks	Course Type: Core
	CIA: 20 + 20 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Basic Mathematics

Course Objective:

1. To make the students aware of different type of data sets and their graphical representations introducing of descriptive statistical measures, including those for two variables.

Course Outcomes: After completion of this course student will able to

1. Understand basic concepts of statistical data.
2. Recognize different diagrammatic tools for visualization of data
3. Apply different statistical measures to describe the data.
4. Assess relationship between two variables.
5. Interpret the statistical results

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
1.	Meaning and scope of the word 'Statistics'. Data types, measurement of scale, classification and tabulation, graphical and diagrammatic representation: Bar diagrams, multiple and stack bar diagrams, histogram, frequency polygon, frequency Curve, O- give, Pie-diagram, Boxplot, Stem and leaf diagrams. Measures of Central Tendency: Concept, requirements of a good measure. mathematical average, positional average with properties, merits and demerits. weighted average, combined mean, Graphical method of determination of Median, Mode and Quartile.	15
2.	Measures of Dispersion: Concept, requirements of a good measure of dispersion, absolute and relative measure, Range, quartile deviation, mean deviation, variance and standard deviation with its coefficient, combined variance, interrelationship between the range, QD, MD and SD. Minimal properties of MD and mean square deviation with proof. Moments: Raw and central moments, relationship between raw and central moments, Sheppard correction for moments (without derivations), skewness, type and its, measurement of skewness. Kurtosis, types and its measurement.	15
3.	Bivariate Data. Scatter diagram. The concept of dependency, illustrative real-life examples. Covariance: Definition, Effect of change of origin and scale. Karl Pearson's coefficient of correlation (r): Definition, Properties, Spearman's rank correlation coefficient: Definition, Interpretation. Derivation of the formula for without ties and Modification of the formula for with-ties computation, variance of linear combination of variables. Correlation coefficient for discrete frequency	15

distribution.

4. Concept of regression, Lines of regression, Principal of least square and cure fitting. Fitting of lines of regression by the least square method. Regression coefficients (b_{xy}, b_{yx}) and their geometric interpretations, Properties. Derivation of the point of intersection of two regression lines and the acute angle between the two lines of regression. 15

Assessment:

CIA:	I	Written
	II	Written/Assignment/Viva/Presentation
ESE	ESE	Written

Reference/Text Books:

- Rohatgi, V. K., & Saleh, A. M. E. (2015). An introduction to probability and statistics. John Wiley & Sons.
- Mukhopadhyay, P. (2012), Mathematical Statistics, new Central Book Agency Pvt. Ltd., Calcutta.
- Hoel P. G. (2016). Introduction to Mathematical Statistics, Asia Publishing House.
- Meyer, P. L. (1965). Introductory probability and statistical applications. Oxford and IBH Publishing.
- Roussas, G. G. (1997). A course in Mathematical Statistics. Elsevier.
- Goon, A. M. (1987). Fundamentals of Statistics Vol. 1. The world press.

COs – POs Mapping matrix STA 111/4.5STA01: Descriptive Statistics
(1-low, 2-medium, 3-high)

PO→ CO↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	1	1	1	1
CO-2	2	2	1	1	2
CO-3	2	3	1	1	3
CO-4	2	2	1	1	1
CO-5	1	1	2	1	1
Total	**9**	**9**	**6**	**5**	**8**
Average	**1.8**	**1.8**	**1.2**	**1**	**1.6**

Course Name: Data Visualization and Interpretation		**Course Code: STA 141 /4.5STA41**
Teaching Scheme	**Examination Scheme**	**Credit : 3**
Theory: 2 hrs/ week	ESE: 60 Marks	
Practical: 2 hrs/week	CIA: 20 + 20 Marks	
Course Type: IDC	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Basic Mathematics

Course Objective:

2. To make the students aware of different data visualization tools.

Course Outcomes: After completion of this course student will able to

1. Understand basic concepts of data.
2. Recognize different diagrammatic tools for visualization of data.
3. Apply different statistical measures to visualize the data.
4. Assess relationship between variables under study.
5. Interpret the statistical results.

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
1.	Chart formatting: Title, subtitle, Axis labels, legends, format selection. Maps, Axis label.	15
2.	Different scales of measurement, Descriptive Statistics for univariate and bivariate data. Bar chart, error bars, different types of the bar chart, Pie chart, doughnut chart. Area Chart, Stacked Area Chart, Bubble Chart.	15
3.	Stock plot, radar plot, line charts, boxplot, histogram, sunburst plot, radar plot, surface plot, Heat Map Chart, scatter plot, bubble plot, 2D and 3D plots. Applications in different area.	15

Reference/Text Books:

1. Healy K. (2021) Data Visualization, Priceton University Press.
2. Grant R. (2023) Data Visualization, CRC Press.

Course Name: Data Analysis using Excel		**Course Code: STA 151/4.5STA51**
Teaching Scheme	**Examination Scheme**	**Credit: 3**
Theory: 2 hrs/ week	ESE: 60 Marks	**Course Type: SEC**
Practical: 2 hrs/ week	CIA : 20 + 20 Marks	
HYBRID Examination	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Excel
2. Basic mathematics

Course Objective:

This course introduces fundamental concepts of Microsoft excel with focus on excel functions are used for statistical data. The course emphasizes the basic concept of statistics, visualization and manual statistical calculation by using excel.

Course Outcomes: After completion of this course student will able to

1. Enter, clean, transform, merge and reshape data.
2. Implement excel function on statistical data.
3. Create informative visualization of data set.
4. Arrange and short the statistical data for basic statistical analysis.
5. Apply Excel for performing basic statistical analysis including correlation and regression.

Course Content:

Unit	**Unit Contents**	**No. of hrs**
1.	Basic of Excel: Format cell, find and select, Data Validation, Keyboard shortcut.	10
2.	Excel Functions: Count and sum, logical, cell reference, date and time, lookup & reference, round, shorting and filtering, logical function.	10
3.	Data storage and data representation: Data storage, pivot table, frequency table, Various chart: Bar chart, Pie chart, Line Chart, Ogive, frequency curve and frequency polygon	10
4.	Statistical Function in excel: calculation of mean, median and mode for frequency data, pivot table, pivot chart. Correlation and curve fitting simple linear regression.	15

Assessment:

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE	-	Written

Reference/ Text Books:

1. David, M. (2017). Statistics for managers, using Microsoft excel. Pearson Education India.
2. Larson, R., & Farber, B. (2019). Elementary statistics. Pearson Education Canada.
3. Moriarty, B., Held, B., & Richardson, T. (2022). Microsoft Excel Functions and Formulas: With Excel 2021/Microsoft 365. Stylus Publishing, LLC.

E-Resources:

Microsoft Excel Step by Step (Office 2021 and Microsoft 365).
URL: Microsoft Excel Step by Step (Office 2021 and Microsoft 365) (pearsoncmg.com)

COs – POs Mapping matrix for STA STA 151/4.5STA51: Introduction to Excel (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	1	1	1	1	1
CO-2	2	2	1	2	2
CO-3	2	3	1	1	1
CO-4	1	1	1	1	1
CO-5	2	3	3	1	3
Total	**8**	**10**	**7**	**6**	**8**
Average	**1.6**	**2**	**1.4**	**1.2**	**1.6**

SEMESTER II

Course Name: Probability and Random Variables		**Course Code: STA 112/4.5STA02**
Teaching Scheme	**Examination Scheme**	**Credit : 4**
Theory: 4 hrs/ week	ESE: 60 Marks	**Course Type: Core**
	Internal Assessments: 20 + 20 Marks	
	Total Marks: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Descriptive Statistics
2. Set Theory
3. Calculus

Course Objective:

1. To introduce the notion of probability, random variable and expectation, based on which statistical theory and tools have been developed.

Course Outcomes: After completion of this course student will able to

1. Recall concept of probability and related terminology
2. Differentiate discrete and continues random variables and its distribution..
3. Understand probability mass function, density function and distribution function.
4. Compute expectations of random variables.
5. Examine peakedness and skewness of distribution

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
1.	Concepts of experiments: deterministic, probabilistic, outcomes of experiments. Sample space, Discrete (finite and countably infinite) and continuous sample space, Event, Elementary event, Compound event. Algebra of events (Union, Intersection, Complementation), De Morgan's law. Definitions of Mutually exclusive events, Exhaustive events, Venn diagram. Definition; Axiomatic definition of probability; Addition theorem (Proof of the result up to three events), Elementary properties, Classical definition of Probability as a special case, Probability as an approximation to the relative frequency, illustrative examples for computation of events based on Permutations and Combinations, with and without replacements, impossible events, certain events. Definition of conditional probability of an event, Multiplication theorem for two events, Independence of events: Pairwise and Mutual Independence of events. Partition of sample space. Statement and proof of Bayes' theorem.	15
2.	Definition of random variable, Discrete and continuous and mixed type of random variables, Definition of distribution function, Distributions function (df) of random variable, Probability distribution of function of random variable. Probability mass function (p.m.f.) and cumulative distribution function (c.d.f.) of a discrete random variable, Probability density function (p.d.f.) and cumulative distribution function (c.d.f.) of a continuous random variable, relation between df and pmf/pdf, Median and Mode of a univariate discrete and continuous random variables.	15

3. Definition of expectation of a random variable, expectation of a function of a random variable, simple properties, Definitions of mean, variance of univariate distributions, Effect of change of origin and scale on mean and variance, Definition of raw, central moments, mean deviation. Pearson's coefficient of skewness, kurtosis, Definitions probability generating function (p.g.f.), moment generating function (MGF), Cumulant Generating function (CGF) and characteristic function (CF) of a random variable, Effects of change of origin and scale. p.g.f. of sum of two independent random variables is the product of p.g.f.s (statement only), Derivation of mean and variance by using p.g.f. 15

Assessment:

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE	-	Written

Reference/ Text Books:

1. Mood A. M., Grabyll R. A. and Boes D. C., Introduction to the theory of Statistics, Tata McGraw Hill
2. Mukhopadhyay, P., Mathematical Statistics, new Central Book Agency Pvt. Ltd., Calcutta.
3. AM Goon, M K Gupta and B. Das Gupta, Fundamentals of Statistics, Volume-I, World Press.
4. Ross Sheldon M., Introduction to Probability Models, Academic Press
5. Rao, B. L. S. Prakash, A first course in probability and Statistics, World Scientific.

COs – POs Mapping matrix for STA 112/4.5STA02: Probability and Random Variables

(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	1
CO-2	1	3	1	1	1
CO-3	2	3	2	1	1
CO-4	1	2	2	1	1
CO-5	2	2	2	1	1
Total	**9**	**12**	**8**	**5**	**5**
Average	**1.8**	**2.4**	**1.6**	**1**	**1**

Course Name: Introduction to R		**Course Code: STA 152/4.5STA52**
Teaching Scheme	**Examination Scheme**	Credit **3**
Theory: 2 hrs/ week	ESE: 60 Marks	**Course Type: SEC**
Practical: 2 hrs/week	Internal Assessments: 20 + 20 Marks	
HYBRID EXAM	Total Marks: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Basic computer skills.

Course Objective:

1. To introduce the notion of probability, random variable and expectation, based on which statistical theory and tools have been developed.

Course Outcomes: After completion of this course student will able to

1. Understand and use the R environment, help system, and packages.
2. Create and manage R data structures for data analysis.
3. Import, store, and export data from multiple sources in R.
4. Write R programs using functions, conditions, and loops for data manipulation.
5. Visualize and interpret data using appropriate charts and plots.

Course Content:

Unit	**Unit Contents**	**No. of hrs**
1.	**Introduction to R**: What is R?, Why R?, Installing R, R environment, How to get help in R, R console and Editor, Installation of r-packages and libraries. **Understanding R data structure:** Variables in R , Scalars, Vectors, Matrices, List, Data frames, Using c, Cbind, Rbind, attach and detach functions in R, Factors	15
2.	**Importing data**: Reading Tabular Data files, Reading CSV files, Importing data from excel, Accessing database, Saving in R data, Loading R data objects, Writing to files. **Manipulating Data**: Selecting rows/observations, Selecting columns/fields, Merging data, Relabelling the column names, Converting variable types, Data sorting, Data aggregation. **Functions in R**: Commonly used Mathematical Functions, Commonly used Summary Functions, Commonly used String Functions, User-defined functions, local and global variable.	15
3.	**R Programming:** Conditional statements, While loop, For loop, Repeat-break switch Arithmetic operations. **Charts and Plots:** Box plot, Histogram, Pareto charts, Pie chart, Line chart , Scatterplot, Developing graphs.	15

Assessment:

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE		Written

Reference/ Text Books:

1. Gardener, M.(2017). Beginning R: The statistical programming language, Wiley.
2. Lawrence, M., & Verzani, J. (2016). Programming Graphical User Interfaces in R. CRC press. (ebook).
3. Wickham, H., Çetinkaya-Rundel, M., & Grolemund, G. (2023). *R for data science*. " O'Reilly Media, Inc.".
4. Tattar, P. N., Ramaiah, S., & Manjunath, B. G. (2016). *A Course in Statistics with R*. John Wiley & Sons.

COs – POs Mapping matrix for STA 152/4.5STA52: Introduction to R

(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	2	1	2	2
CO-2	3	2	2	1	2
CO-3	2	2	3	1	2
CO-4	2	2	3	1	2
CO-5	2	3	2	1	3
Total	11	11	11	6	11
Average	2.2	2.2	2.2	1.2	2.2

SEMESTER III

Course Name: Probability Distributions - I		**Course Code: STA 211/5.0STA01**
Teaching Scheme	**Examination Scheme**	**Credit : 4**
Theory: 4 hrs/ week	ESE: 60 Marks CIA: 20 + 20 Marks Total: 100 Marks	**Course Type: Core**

Course Pre-requisites: Student must have knowledge of

1. Basic Probability
2. Descriptive Statistics
3. Calculus

Course Objective:

1. The main objective is to introduce standard discrete and continuous distributions

Course Outcomes: After completion of this course student will able to

1. Differentiate discrete and continues random variables and its distribution.
2. Recognize basic probability distributions and their properties.
3. Identify distributions of functions of random variables.
4. Differentiate between sampling and exact sampling distributions.
5. Use various distributions for variety of real life situations.

Course Content:

Unit	**Unit Contents**	**No. of hrs**
1.	Discrete Distribution: General concept of a finite discrete random variable De-generate, Discrete Uniform, Bernoulli, Binomial, Poisson with their properties such as mean, variance, moments, MGF, CGF, PGF and applications such as limiting distribution property.	20
2.	Geometric, Negative Binomial, Hyper geometric and Multinomial distributions with their properties such as mean, variance, moments MGF, CGF, PGF and applications.	20
3.	Continuous Distribution: Rectangular, Exponential, Gamma, and Beta (I and II kind). Normal Distribution with their properties such as mean, variance, moments, MGF, CGF, CF and applications such as limiting distribution property.	20

Assessment:

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE	ESE	Written

Reference/ Text Books:

1. Hogg, R. V., & Craig, A. T. (1995). Introduction to mathematical statistics. (5"" edition). Englewood Hills, New Jersey.
2. Hogg, R. V., Tanis, E. A., & Zimmerman, D. L. (1977). Probability and statistical inference (Vol. 993). New York: Macmillan.

3. Hogg, R. V., & Craig, A. T. (1995). Introduction to mathematical statistics. (5"" edition). Englewood Hills, New Jersey.
4. Hogg, R. V., Tanis, E. A., & Zimmerman, D. L. (1977). Probability and statistical inference (Vol. 993). New York: Macmillan.
5. Mayer P.L. (1965). Introductory probability & Statistical Applications. Addison Weseley Publication Co., London
6. Goon A.M., Gupta A.K. and Dasgupta B. (2016). Fundamentals of Statistics (Vol. II) World Press, Calcutta.

COs – POs Mapping matrix for STA 211/5.0STA01: Probability Distributions - I (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	1	1	2	2
CO-2	2	3	1	2	1
CO-3	3	3	1	2	3
CO-4	2	2	1	3	2
CO-5	3	3	3	2	2
Total	**13**	**12**	**7**	**11**	**10**
Average	**2.6**	**2.4**	**1.4**	**2.2**	**2**

Course Name: Statistical Methods		Course Code: STA212/5.0STA02
Teaching Scheme	**Examination Scheme**	**Credit : 4**
Theory: 4 hrs/ week	ESE: 60Marks CIA: 40 Marks Total: 100 Marks	**Course Type: Core**

Course Pre-requisites: Student must have knowledge of
Basic concepts in the descriptive statistical measures, methods of estimating and testing of hypotheses.

Course Objective:

1. To understand the concepts of regression and its properties with applications.
2. To get the knowledge on sampling distributions and tests of significance on them.
3. To classify various parametric and non-parametric statistical techniques in various real life applications.
4. To test the significance of proportions, means and standard deviations of the give test of hypotheses.
5. To know the method of estimation, confidence interval and to test the equality of means, variances of normal populations.

Course Outcomes: After completion of this course student will able to

1. understand the concepts of regression and correlations with applications.
2. understand the sampling distributions and its tests of significance.
3. apply parametric and non-parametric statistical techniques.
4. test the significance of proportions, means and standard deviations of the give test of hypotheses.
5. estimate the parameters, confidence interval and to test the equality of means, variances of normal populations.

Course Content:

Unit	Unit Contents	No. of hrs
1	**Curve Fitting: Method of least square.** - Fitting of a Straight Line - Fitting of a Second order Polynomial curve. - Fitting of Exponential and Logarithmic curve.	15
2	Multiple and Partial Correlation , Yule's Notation, Plane of Regression, Generalization, Properties of Residuals, Variance of the Residuals , Coefficient of Multiple Correlation, Properties of Multiple Correlation 'Coefficient, Coefficient of Partial Correlation, Generalization, Multiple Correlation in Terms of Total and Partial Correlations.	15

3	Theory of attributes: Independence and association of attributes. measures of association for two way classified data. consistency and independence of data with special reference to attributes. coefficient of colligation.	15
4	Hypothesis testing: Introduction to hypothesis testing. Problems of testing of hypothesis, critical region. Test of significance for small and large samples: tests for single proportion, difference of proportions. test of significance for single mean, single variance, difference of means, Paired sample test and difference of standard deviations.	15

Assessment:

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE	-	Written

Reference/ Text Books:

1. Conover, W. J., Practical Non-Parametric Statistics, third edition, John Wiley, NY, 2007.
2. Goon, M., Gupta, M.K. and Dasgupta, B. (2003). An outline of Statistical Theory, Vol. I, 4th Ed., World Press, Kolkata.
3. Hogg, R. V., McKean, J., and Craig, A. T. (2005). Introduction to mathematical statistics. Pearson Education.
4. Kennedy, W. J. and Gentle, J. E., Statistical Computing, Taylor & Francis, 1980.
5. Mood, A.M. Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn., (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
6. Snedcor, G. W. and Cochran, W. G., Statistical Methods, seventh edition, Iowa State University Press, 1982.
7. Tanner, M. A., Tools for Statistical Inference, Springer-Verlag, 2011.

COs – POs Mapping matrix for STA212/5.0STA02: Statistical Methods (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	2	1	3
CO-2	3	3	2	1	3
CO-3	3	3	2	1	3
CO-4	3	3	3	1	3
CO-5	3	3	3	1	3
Total	15	15	12	5	15
Average	3	3	2.4	1	3

Course Name: Fundamental of Data Collection and Analysis		**Course Code: STA251/5.0STA51**
Teaching Scheme	**Examination Scheme**	**Credit 03**
Theory: 3 hrs/ week	ESE: 60Marks CIA: 40 Marks Total: 100 Marks	**Course Type: IDC**

Course Pre-requisites: Student must have knowledge of

- Basic concepts in the descriptive statistical measures, methods of estimating and testing of hypotheses.

Course Objective:

1. to design the questionnaire and conduct the surveys.

Course Outcomes: After completion of this course student will able to

1. Design questionnaire.
2. Collect primary data using designed questionnaire.
3. Analyse the collected data.
4. Test the reliability of the data

Course Content:

Unit	Unit Contents	No. of Hrs
1	Definitions of statistical population, finite population, infinite population, homogeneous and heterogeneous population. Preparation of questionnaire: Definition, Characteristics of a good questionnaire, advantages & disadvantages of questionnaire. Types of questionnaires - Descriptive Questionnaire, Analytical Questionnaire	10
2	Types of questions in questionnaire - Open-Ended Questions (Unstructured), Close-Ended questions (structured), Dichotomous Questions, Multiple Choice Questions, Scaling Questions, Pictorial Questions.	10
3	Designing of questionnaire – aim, simplicity in language, balance framing (number of questions), question order, terminology, Examples of questionnaires in different fields	10
4	Tools for designing questionnaire – Google form, Microsoft Team, survey planet or monkey, Form Façade etc. Mode/ Method of collection of questionnaires – postal, interview, in-house, social media. Tests for validity & Reliability of data from questionnaire – Cronbach's alpha. Analysis & Report on collected data through questionnaire.	15

References /Text books

1. Kothari, C.R. (2004) Research Methodology: Methods and Techniques. 2nd Edition, New Age International Publishers, New Delhi.
2. Bethlelem, J. (2008) Applied Survey Methods a Statistical Perspective. John Wiley & Sons, Hoboken.
3. Peytcheva, E. Yan, T. (2025) A Practical Guide to Survey Questionnaire Design and Evaluation, Taylor & Francis.

COs – POs Mapping matrix for STA251/5.0STA51: Fundamental of Data Collection and Analysis
(1-low, 2-medium, 3-high)

PO→ CO ↓	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**
CO-1	2	2	3	1	3
CO-2	2	3	3	1	3
CO-3	3	3	3	1	3
CO-4	3	3	3	1	3
Total	10	11	12	4	12
Average	2.5	2.75	3	1	3

Course Name: Statistical Computing - I		Course Code: STA261/5.0STA61
Teaching Scheme	**Examination Scheme**	**Credit : 2**
Practical: 4 hrs/ week	ESE: 60 Marks CIA: 40 Marks Total: 100 Marks	**Course Type: Core**

Course Pre-requisites: Student must have knowledge of

1. Basic concepts in the descriptive statistics, probability, random variable and testing of hypotheses.
2. Basic R programming skills

Course Objective:

1. To understand the different types of statistical data
2. To test the significance of proportions, means and standard deviations of the give test of hypotheses.
3. To understand the concepts of regression and its properties with applications.
4. To generate random data and get the knowledge on probability distributions.

Course Outcomes: After completion of this course student will able to

1. analyse different types of statistical data using R
2. test the the significance of proportions, means and standard deviations of the give test of hypotheses using R
3. understand the concepts of regression and correlations with applications using R.
4. generate random data and analyse the probability distributions using R.
5. apply R to visualize multivariate data and interpret relationships among variables.

Course Content:

Unit	Unit Contents	No. of hrs
1	Review on graphics in R – plot, boxplot, pie, scatterplot3d. Advanced graphics-ggplot2, Lattice. Types of statistical data: Univariate, Bivariate and Multivariate. Bivariate Data: categorical data, categorical vs. numerical, numerical vs. numerical. Multivariate Data: Storing multivariate data in data frames, Accessing data in data frames, Manipulating data frames: stack and unstack, Visualization of Multivariate Data- panel displays, correlation plots.	20
2	Random Generators of Common Probability Distributions and its properties in R: Beta, binomial, exponential, gamma, geometric, negative binomial, normal, Poisson, uniform. Sums of independent random variables (convolutions).	20

3	Correlation-Multiple and Partial, regression lines, residuals and it's properties. Hypothesis Testing: Testing of a population parameter, of mean, standard deviations, proportions, t-test. Chi Squared Test: goodness of fit, of independence and for homogeneity.	20

Assessment:

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE	-	Written

Reference/ Text Books:

1. Gardener, M.(2017). Beginning R: The statistical programming language, Wiley.
2. Lawrence, M., & Verzani, J. (2016). Programming Graphical User Interfaces in R. CRC press. (ebook).
3. Wickham, H., Çetinkaya-Rundel, M., & Grolemund, G. (2023). *R for data science*. " O'Reilly Media, Inc.".
4. Tattar, P. N., Ramaiah, S., & Manjunath, B. G. (2016). *A Course in Statistics with R*. John Wiley & Sons.
5. Maria L. Rizzo. (2019). Statistical Computing with R, Second Edition, CRC Press, Taylor & Francis Group.

COs – POs Mapping matrix for STA261/5.0STA61: Statistical Computing - I (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	3	2	1	3
CO-2	3	3	3	1	3
CO-3	3	3	2	1	3
CO-4	3	3	2	1	3
CO-5	3	3	3	2	3
Total	**14**	**15**	**12**	**6**	**15**
Average	**2.8**	**3**	**2.4**	**1.2**	**3**

Semester IV

Course Name: Probability Distributions–II		**Course Code: STA 213 /5.0STA03**
Teaching Scheme	**Examination Scheme**	**Credit 4**
Theory: 4 hrs/ week	ESE: 60 Marks	**Course Type: Core**
	CIA: 20 + 20 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Basic Probability
2. Descriptive Statistics
3. Calculus

Course Objective:

1. The main objective is to introduce standard discrete and continuous distributions

Course Outcomes: After completion of this course student will able to

1. Differentiate discrete and continues random variables and its distribution.
2. Recognize basic probability distributions and their properties.
3. Identify distributions of functions of random variables.
4. Differentiate between sampling and exact sampling distributions.
5. Use various distributions for variety of real life situations.

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
1.	Concept of bivariate r.v. and their distribution function. Discrete and Continuous Bivarate random variables. Marginal Distribution, Bivariate Moments, Bivariate MGF. Conditional Distribution. Conditional Expectation and Conditional Variance. Covariance and Correlation of Bivariate rvs.	15
2.	Function of random variables in one dimensional and two dimensional using (i) Distribution function (ii) M.G.F. technique and (iii) Jacobian of transformation	10
3.	Exact sampling distributions: Chi square distribution, Student's *t*-distribution and Snedecor's F distribution. Definitions, derivation of p.d.fs, sketch of p.d.fs. for various values of parameter, moments. Inter relation between t, F and χ^2. Applications of t, F and $\chi 2$ distributions.	18
4.	Order statistics: Definition, derivation of PDF of i-th order statistics, for a random sample of size *n*. Density of smallest and largest observations. Derivation of joint pdf of i^{th} and j^{th} order statistics, Statement of distribution of the sample range. Distribution of the sample median and distributions of spacing.	17

Reference/ Text Books:

1. Hogg, R. V., & Craig, A. T. (1995). Introduction to mathematical statistics. (5"" edition). Englewood Hills, New Jersey.
2. Hogg, R. V., Tanis, E. A., & Zimmerman, D. L. (1977). Probability and statistical inference (Vol. 993). New York: Macmillan.
3. Mayer P.L. (1965). Introductory probability & Statistical Applications. Addison Wiseley Publication Co., London
4. Goon A.M., Gupta A.K. and Dasgupta B. (2016). Fundamentals of Statistics (Vol. II) World Press, Calcutta.

COs – POs Mapping matrix for STA 213 /5.0STA03: Probability Distributions-II

(1-low, 2-medium, 3-high)

PO→ CO ↓	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**
CO-1	3	1	1	2	2
CO-2	2	3	1	2	1
CO-3	3	3	1	2	3
CO-4	2	2	1	3	2
CO-5	3	3	3	2	2
Total	**13**	**12**	**7**	**11**	**10**
Average	**2.6**	**2.4**	**1.4**	**2.2**	**2**

Course Name: Applied Statistics		**Course Code: STA 214/5.0STA04**
Teaching Scheme	**Examination Scheme**	**Credit 4**
Theory: 4 hrs/ week	ESE: 60 Marks	**Course Type: Core**
	CIA: 20 + 20 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Mathematical statistics measures, variables and its independency.

Course Objective: After completion of this course student will able to

1. Find and understand different Index numbers.
2. Find the various vital statistical measures.
3. Learn about demographic measures and its models.
4. Understand the time series analysis and its seasonal trends by using moving averages.
5. Know the official statistics and also to know the corresponding organizations in India.

Course Outcomes: After completion of this course student will able to

1. Compute various Index numbers in different situations.
2. Calculate the various vital statistical measures.
3. Understand the demographic measures and its models.
4. Understand the trend of a product or an item in different time periods.
5. Applicability of the official statistical measures in census.

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
1.	Index Numbers: Meaning and utility of index numbers, problems in construction of index numbers. Unweighted and weighted index numbers using (i) aggregate method, (ii) average of price or quantity relative. Link and chain relatives' composition of index numbers. Construction of cost of living index number and wholesale price index number. Uses and limitations of index numbers. Criteria for a good index number	12
2.	Vital Statistics: Introduction and sources of vital statistics. Measurements of Mortality: Crude Death Rate (CDR), Specific Death Rate (SDR), Infant Mortality, Rate (IMR) and Standardized Death Rates. Life (Mortality) Tables: Assumption, description, construction of Life Tables and Uses of Life Tables. Measurements of Fertility: Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR) and Total Fertility Rate (TFR). Gross Reproduction Rate (GRR) and Net Reproduction Rate (NRR).	12
3.	Scope and content of population census of India. Population, Composition, Dependency ratio, Errors in demographic data, Adjustment of age data. Chandrasekhar – Deming formula to check completeness of registration data.	12

Models for population growth-Linear, Exponential, logarithmic, modified logarithmic, Gompertz and Logistic Curves.

4. Introduction to times series, Components of a times series. Trend: Estimation of trend, method of semi averages, fitting a various mathematical curve, and growth curves. Method of moving averages. Estimation of seasonal component by Method of simple averages, Ratio to Trend, Ratio to Moving Averages and Link Relative method. 12

5. Indian Official Statistics: Present Official Statistical System in India relating to census of population, agriculture, industrial production, and prices; methods of collection of official statistics, their reliability and limitation and the principal publications containing such statistics. Also, the various agencies responsible for the data collection- C.S.O., N.S.S.O., Office of Registrar General, their historical development, main functions and important publications. 12

Assessment:

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE	ESE	Written

Reference/ Text Books:

1. Chatfield C. (1980): The Analysis of Time Series –An Introduction, Chapman & Hall.
2. Cox, P.R. (1970): Applied Mathematical Demography, Springer Verlag.
3. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition, World Press.
4. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals of Applied Statistics, 4th Edition (Reprint), Sultan Chand & Sons
5. Kendall M.G. (1976): Time Series, Charles Griffin.
6. Keyfitz N., Beckman John A.: Demogrphy through Problems S-Verlag New York.
7. Mukhopadhyay P. (2011): Applied Statistics, 2nd ed. Revised reprint, Books and Allied
8. Spiegelman, M. (1969): Introduction to Demographic Analysis; Harvard University Press.

COs – POs Mapping matrix for STA 214/5.0STA04: Applied Statistics
(1-low, 2-medium, 3-high)

PO→ CO ↓	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**
CO-1	3	2	1	1	2
CO-2	3	2	2	1	3
CO-3	3	3	2	1	3
CO-4	3	3	2	1	3
CO-5	3	2	1	2	3
Total	**15**	**12**	**8**	**6**	**14**
Average	**3**	**2.4**	**1.6**	**1.2**	**2.8**

Course Name: Statistical Inference-I		**Course Code: STA215/5.0STA05**
Teaching Scheme	**Examination Scheme**	**Credit 4**
Theory: 4 hrs/ week	ESE: 60 Marks CIA: 20 + 20 Marks Total: 100 Marks	**Course Type: Core**

Course Pre-requisites: Student must have knowledge of

1. Descriptive statistical measure
2. Probability and Random Variables
3. Probability Distribution

Course Objective:

1. The main objective is to build the theoretical foundation of Point Estimation and Testing of hypothesis and to introduce the notion of order statistics

Course Outcomes: After completion of this course student will able to

1. Understand concept of order statistics and its applications
2. Recognize basic concepts of statistical inference.
3. Recognize different methods of parameter estimation
4. Recall various properties of estimators
5. Apply different statistical test procedures for different testing of hypothesis problems.

Course Content:

Unit	**Unit Contents**	**No. of hrs**
1.	Concept of Statistical inference, sampling method and complete enumeration, Definition of population, parameter, parameter space. Point estimation: Definition of an estimator (Statistic) and its Standard Error, distinction between estimator and estimate.	15
2.	Methods of estimation: methods of moments, Estimation of the parameters of normal distribution and other standard distributions by method of moments. Concept of likelihood function, Maximum Likelihood Estimator (MLE), Properties of MLE (without proof), Estimation of the parameters of normal distribution and other standard distributions by MLE.	15
3.	Properties of an estimators: Unbiased estimator, parametric function, biased estimator, positive and negative bias, examples of unbiased and biased estimator, properties of unbiased estimators. Relative efficiency of estimators. Use of mean square error (MSE) to modify the above definition for biased estimators. Sufficiency: Concept of sufficiency, Definition of sufficient statistic through conditional distribution of the sample given the statistics. Neyman factorization criterion, Pitmann-Koopman form which admits sufficient statistic. Properties of sufficient statistic. Definitions of Consistency, Sufficient condition for consistency.	15
4.	Interval Estimation: Notion of interval estimation, Definition of confidence	15

interval, length of confidence interval, confidence bounds. Definition of pivotal quantity and its use in obtaining confidence intervals and bounds. Interval estimation for the following cases: 1) mean of normal distribution (variance known and unknown). 2) variance of normal population (man known and unknown). 3) mean differences of two normal populations 4) population proportions 5) Mean of exponential distribution.

Reference/ Text Books:

1. George Casella, Roger L. Berger (2002), Statistical Inference, 2nd ed., Thomson Learning.
2. Mukhopadhyay P. (1996): Mathematical Statistics, New central Book Agency (P) Ltd. Calcutta
3. Rohatgi, V.K. (1984): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.
4. Goon, Gupta & Das Gupta (1991): An Outline of Statistical Theory, Vol. II, World Press.
5. Hogg, R.V. and Craig, A.T. (1971): Introduction to Mathematical Statistics, McMillan.

COs – POs Mapping matrix for STA215/5.0STA05: Statistical Inference-I
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	3	2	1
CO-2	3	3	3	1	1
CO-3	2	2	2	1	1
CO-4	2	2	2	1	1
CO-5	3	3	3	2	2
Total	**13**	**12**	**13**	**7**	**6**
Average	**2.6**	**2.4**	**2.6**	**1.4**	**1.2**

Course Name: Statistical Computing – II(AEC)		Course Code: STA262/5.0STA62
Teaching Scheme	**Examination Scheme**	**Credit : 2**
Practical: 4 hrs/ week	ESE: 60 Marks CIA: 40 Marks Total: 100 Marks	**Course Type: Core**

Course Pre-requisites:

Student must have knowledge of

1. Basic concepts in the probability, random variable and testing of hypotheses.
2. Basic R programming skills

Course Objective:

1. To understand the bivariate distributions and exact sampling distributions
2. To understand the order statistics and basics of different estimation methods.
3. To understand the properties estimators.
4. To find various index number, mortality and fertility measures and
5. To find trends, seasonal variations using different time series methods.

Course Outcomes:

After completion of this course student will able to

1. analyse bivariate and exact sampling distributions for the random data using R
2. draw the inferences on order statistics and different parameter estimation procedures using R
3. understand the basic properties of estimators using R.
4. find index numbers and vital statistical measures for the data using R.
5. forecast trends and seasonal variations for the time series data using R

Course Content: (List of Practicals)

1. Generate random numbers from a bivariate Discrete distributions- Binomial, Poisson, Geometric.
2. Generate random numbers from a bivariate continuous Distributions-Uniform, Normal and Exponential
3. Find Joint and marginal Probability Mass Functions for Bivariate Discrete Distributions.
4. Find Joint and marginal Probability Density Functions for Bivariate Continuous Distributions.
5. Find Cumulative Distribution Function for Bivariate Discrete Distributions.

6. Find Cumulative Distribution Function for Bivariate Continuous Distributions.
7. Find Maximum Likelihood Function for Bivariate Continuous Distributions.
8. Find Maximum Likelihood Function for Bivariate Continuous Distributions.
9. Analyse exact sampling distributions (t, Chi-Square and F) for the random data using R
10. Draw the inferences on order statistics and different parameter estimation procedures using R
11. Problems on Unweighted, weighted Index Numbers.
12. Problems on Cost of living index number and wholesale price index number.
13. Problems on Measurements of Mortality: CDR, SDR, IMR and SDR.
14. Measurements of Fertility: CBR, GFR, SFR and TFR. GRR and NRR.
15. Plot the Exponential, logarithmic, Gompertz and Logistic Curves.
16. Problems on Fitting of Exponential Trend.
17. Problems on Fitting of Linear Trend.
18. Problems on Simple Moving Average Method.
19. Problems on Exponential Smoothing Method.
20. Problems on Ratio to Trend Method.

Assessment:

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE	-	Written

Reference/ Text Books:

1. Balasubramanian Narasimhan, Steven G. Johnson, Thomas Hahn, Annie Bouvier and Kiên Kiêu (2023). cubature: Adaptive Multivariate Integration over Hypercubes. R package version 2.0.4.6. https://CRAN.R-project.org/package=cubature.
2. Ben Bolker, Gregory R. Warnes and Thomas Lumley (2022). gtools: Various R Programming Tools. R package version 3.9.3. https://CRAN.R-project.org/package=gtools
3. Gardener, M.(2017). Beginning R: The statistical programming language, Wiley.
4. Hadley Wickham (2019). stringr: Simple, Consistent Wrappers for Common String Operations. R package version 1.4.0. https://CRAN.R-project.org/package=stringr
5. Lawrence, M., & Verzani, J. (2016). Programming Graphical User Interfaces in R. CRC press. (ebook).
6. Maria L. Rizzo. (2019). Statistical Computing with R, Second Edition, CRC Press, Taylor & Francis Group.
7. Tattar, P. N., Ramaiah, S., & Manjunath, B. G. (2016). *A Course in Statistics with R*. John Wiley & Sons.

8. R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/
9. Wickham, H., Çetinkaya-Rundel, M., & Grolemund, G. (2023). *R for data science*. " O'Reilly Media, Inc.".

COs – POs Mapping matrix for STA261/5.0STA61: Statistical Computing - I (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	2	1	3
CO-2	3	3	3	1	3
CO-3	3	3	2	1	3
CO-4	3	2	2	1	3
CO-5	3	3	2	1	3
Total	**15**	**14**	**11**	**5**	**15**
Average	**3**	**2.8**	**2.2**	**1**	**3**

Semester V

Course Name: Design of Experiments		**Course Code: STA 311/5.5STA01**
Teaching Scheme	**Examination Scheme**	**Credit : 4**
Theory: 4 hrs/ week	ESE: 60 Marks	**Course Type: Core**
	CIA: 20+20 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Normal, Chi-square, t, and F distributions, t-test

Course Objective:

1. Enable to plan, design and conduct experiments efficiently and effectively, and analyze the resulting data to obtain objective conclusions.

Course Outcomes: After completion of this course student will able to

1. Understand the potential practical problems and applications of design of experiments in various fields.
2. Build a deeper understanding, and tools for analysis of experiments.
3. Describe how the analysis of the data from the experiment should be carried out.
4. Use a statistical computing package to analyse real-life data.
5. Appreciate the advantages and disadvantages of a design for a particular experiment.

Course Content:

Unit	**Unit Contents**	**No. of hrs**
1.	Basic terms in design of experiments: Experimental unit, treatment, layout of an experiment, basic principles of design of experiments: Replication, randomization and local control, choice of size and shape of a plot for uniformity trials, the empirical formula for the variance per unit area of plots.	15
2.	Completely Randomized Design (CRD), Randomized Block Design (RBD), and Latin Square Design (LSD): layout, mathematical model assumptions and interpretations, estimation of parameters, Standard Error (SE), estimate of σ as square root of Mean Error Sum of Square. Technique of one-way analysis of variance (ANOVA) and its applications, statement of Chochran's theorem (without proof) for justification of F-test. Tests for equality for treatment effects and its interpretation. Test for equality of two specified treatment effects using Critical Difference (CD), Model adequacy check using residual analysis.	20
3.	Missing plot technique: analysis of RBD with single missing observation, analysis of LSD with single missing observation. Analysis of Covariance. CRD with one covariate, RBD with one covariate.	10
4.	General description of factorial experiments, 2^2& 2^3 factorial experiments arranged in RBD. Definitions of main effects and interaction effects in 2^2& 2^3 factorial experiments. Model assumptions and its interpretation. Preparations of ANOVA table by Yate's procedure, test for main effects and interaction effects.	15

Assessment

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE	ESE	Written

Reference/ Text Books:

1. Montgomery, D.C. (2001): Design and Analysis of Experiments, John Wiley and sons Inc., New Delhi.
2. Das, M. N., & Giri, N. C. (1986). Design and analysis of experiments. New Age International.
3. Hinkelmann, K., & Kempthorne, O. (2007). Design and analysis of experiments, volume 1: Introduction to experimental design (Vol. 1). John Wiley & Sons.

COs – POs Mapping matrix for STA 311/5.5STA01: Design of Experiments
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	2	2	1	3
CO-2	2	2	2	1	2
CO-3	1	1	2	2	1
CO-4	2	2	2	1	2
CO-5	2	2	2	1	3
Total	**9**	**9**	**10**	**6**	**11**
Average	**1.8**	**1.8**	**2**	**1.2**	**2.2**

Course Name: Statistical Quality Control and Operations Research		**Course Code: STA312/5.5STA02**
Teaching Scheme	**Examination Scheme**	**Credit: 4**
Theory: 4 hrs/ week	ESE:60 Marks CIA: 20 + 20 Marks Total: 100 Marks	**Course Type: Core**

Course Pre-requisites: Student must have knowledge of probability distributions

Course Outcomes: After completion of this course student will able to

1. Understand the general theory and review of control charts.
2. Apply statistical process control in auto-correlated process data.
3. Perform various sampling plans to reduce consumer and producer risks.
4. Recognize the need of multiple sampling plans.
5. Apply the SQC techniques to analyse the industrial data.

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
1.	Introduction to quality: Concept of quality and its management - quality planning, quality control and quality improvement; concept of variations and its impact, relevance of exploratory data analysis, run plot, lag plot, frequency distribution and other QC tools. Measurement System: Introduction to measurement system; types of measurement; measurement validity; measurement errors and their estimation	15
2.	Use of Control Chart: Introduction to control chart, control chart for variables and attributes - X-MR chart, X-R chart, $\bar{X}$-s chart, p-chart, np-chart and c-chart; u-chart, CUSUM chart, EWMA $\bar{X}$ chart; process capability analysis. Acceptance Sampling: Introduction to acceptance sampling; concept of AQL, LTPD, producer's risk and consumer's risk; single sampling plan and its OC function; acceptance rectification plan - concept of AOQ, AOQL ATI, acceptance sampling tables; concept of double and multiple sampling plan; average sample number.	15
3.	Introduction to Operations Research: Optimization Theory: Mathematical modeling and concept of optimization problems: linear, nonlinear and integer programming problems; formulation and application of optimization problems; convex analysis in optimization theory; linear programming problem - graphical method to solve linear programming problem, simplex algorithm, sensitivity analysis, solution procedure of two person zero-sum games; optimality conditions and duality theory; nonlinear programming problem and its classification.	15
4.	Queuing Theory: Queuing system in practice and importance in Operations Research; pure birth process, birth and death process; introduction to M/M/1 and M/M/C queues; finite queuing system; application of queuing system and limitation.	15

Reference/ Text Books:

1. Statistical Quality Control- E.L. Grant & R.S. Leavenworth, McGraw-Hill, N.Y.
2. Quality Control and Industrial Statistics - A. J. Duncan, Irwin, Homewood, Ill
3. Introduction to Statistical Quality Control- D.C. Montgomery, Wiley, N.Y.
4. Linear and Nonlinear Programming, D. G. Luenberger, Second Edition, Addison-Wesley, Reading, MA, 1984.
5. Linear Programming - G. Hadley, Addison Wesley.
6. Linear Programming - K. G. Murty, John Wiley
2. Linear Programming and Network Flows, M. S. Bazaraa and J. J. Jarvis, John Wiley & Sons, Inc., New York,.
3. Nonlinear Programming: Theory and Algorithms, M. S. Bazaraa, H. D. Sherali, and C. M. Shetty, New York, NY: John Wiley & Sons Inc.
4. Introduction to Operations Research. Hillier and Lieberman, McGraw-Hill, Boston., MA.
5. Numerical Optimization with Applications, S. Chandra, Jayadeva and Aparna Mehra, Narosa Publishing House (2009).

COs – POs Mapping matrix for STA312/5.5STA02: Statistical Quality Control (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	1	2	2	2
CO-2	2	2	2	2	2
CO-3	2	2	2	2	2
CO-4	2	1	3	2	2
CO-5	2	3	3	3	2
Total	**10**	**9**	**12**	**11**	**10**
Average	**2**	**1.8**	**2.4**	**2.2**	**2**

Course Name: Sample Survey		**Course Code: STA 313/5.5STA03**
Teaching Scheme	**Examination Scheme**	**Credit: 4**
Theory: 4 hrs/ week	ESE: 60 Marks	**Course Type: Core**
	CIA: 40 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Descriptive Statistics
2. Basic probability and probability distributions
3. Statistical Inference
4. Knowledge of R

Course Objective: After successfully completing this course, students should ordinarily expect to be able to:

1. Describe the purpose of conducting a survey and its overall process. For examples: principles of a sample survey, importance of sampling over complete enumeration, use of above ideas using real-life survey conducted by NSSO or other agencies.
2. Describe components of survey errors.
3. Describe designing of a questionnaire
4. Describe considerations for designing a sample
5. Describe steps in implementing a sample survey
6. Describe different methods of sampling designs
7. Describe different methods of estimation
8. Describe considerations in calculating estimates based on survey data

Course Outcomes: After completion of this course student will able to

1. Understand the basic principles underlying survey design and estimation.
2. Use of appropriate survey designs under different real-life situations and derive estimators of mean and total and their variances for each sampling design.
3. Implement systematic sampling, cluster sampling and two-stage sampling in real-life problems.
4. Describe different methods of estimation and derive estimators of mean and their MSE for each method of estimation
5. Conduct a sample survey in own domain/interest.

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
1.	Basic concept: Elementary units, sampling units, population, sampling frame, complete enumeration, need of sampling, random sample, requisites of a good sample, complete enumeration versus sampling, basic principles of a sample survey, sampling and non-sampling errors, types of sampling: non-probability and probability sampling, questionnaire and its characteristics, study (questionnaires, sampling design, methods followed in field investigation, principal findings, etc.) of some surveys by National Sample Surveys organization or other agencies.	16

2.	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, exercises. Concept of Stratification, , real life situation where stratification can be used, methods of allocation, estimates of population mean and total, variances of these estimates, methods of allocation, Cost and variance analysis in stratified random sampling, gain in precision due to stratification, comparison amongst SRSWOR, stratification with proportional allocation and stratification with Neyman's, exercises.	18
3.	Systematic Sampling: Real life situations where systematic sampling is appropriate, Technique of drawing a sample using systematic sampling, Estimation of population mean and population total, Comparison of systematic sampling with SRSWOR and stratified sampling in the presence of linear trend. Idea of Circular Systematic Sampling, exercises. Cluster Sampling: Real life situations where cluster sampling is appropriate, technique of drawing a sample using cluster sampling, estimation of population mean and population total (with equal size clusters), concept of sub sampling, two-stage Sampling, Estimation of Population mean and variance of the estimate, exercises.	16
4.	Introduction to ratio, product and regression methods of estimation, Situations where (i) ratio method is appropriate, (ii) product method is appropriate and (iii) regression method is appropriate, estimation of population mean, evaluation of bias and variance to the first order of approximation, comparison with simple random sampling, exercises.	10

Reference/ Text Books:

1. Cochran, W.G. (2007): Sampling Techniques , Third Edition, Wiley India Pvt. Ltd., New Delhi.
2. Murthy, M. N. (1977): Sampling Theory and Methods, Statistical Publishing Society, Kolkata.
3. Cochran, W.G.(2007): Sampling Techniques , Third Edition, Wiley India Pvt. Ltd., New Delhi. 2. Murthy, M. N. (1977): Sampling Theory and Methods, Statistical Publishing Society, Kolkata.
4. Singh, D. and Chaudhary, F. S. (1986): Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.
5. RaghunathArnab (2017): Survey Sampling Theory and Applications, Academic Press, Elsevier.
6. Mukhopadhyay P (2008): Theory and methods of survey sampling. Prentice-Hall of India, New Delhi.

E-Resources:

1. https://nptel.ac.in/courses
2. http://mospi.nic.in/

COs – POs Mapping matrix for STA 313/5.5STA03: Sample Survey
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	1	3	1	2
CO-2	2	1	3	2	2
CO-3	2	2	3	2	1
CO-4	3	3	2	2	2
CO-5	3	3	3	2	3
Total	**13**	**10**	**14**	**9**	**10**
Average	**2.6**	**2**	**2.8**	**1.8**	**2**

Course Name: Practical		**Course Code: STA 314/5.5STA04**
/Teaching Scheme	**Examination Scheme**	**Credit : 4**
Pactical: 8 hrs/ week	ESE: 100 Marks	**Course Type: Core**

Course Outcomes: After completion of this course student will able to

1. Design and conduct experiments using principles of DOE.
2. Analyze experimental data using ANOVA and randomized designs.
3. Apply control charts and other tools for monitoring process quality.
4. Collect, organize, and analyze sample survey data using appropriate sampling methods.
5. Interpret results and make informed decisions from experimental and survey data.

The course content of this course comprise of practical exercises related to Course STA-311 t, 312, 313 to be executed in R-programming language.

COs – POs Mapping matrix for STA 314/5.5STA04: Practical
(1-low, 2-medium, 3-high)

PO→ CO ↓	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**
CO-1	3	3	2	1	3
CO-2	3	3	3	1	3
CO-3	2	3	3	1	3
CO-4	3	3	3	1	3
CO-5	2	3	3	1	3
Total	**13**	**15**	**14**	**5**	**15**
Average	**2.6**	**3**	**2.8**	**1**	**3**

Course Name: Foundations and Growth of Statistics in India		**Course Code:**
Teaching Scheme	**Examination Scheme**	**Credit : 2**
Theory: 2 hrs/ week	ESE: 60 Marks	Course Type: IKS
	CIA: 20 + 20 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Basic Mathematics

Course Objective:

1. This course aims to provide students with a comprehensive understanding of the historical evolution of statistics and probability in India

Course Outcomes: After completion of this course student will able to

1. Understand the role of statistics in the history of India.
2. Use of probability in ancient time.
3. Understand role of different Statistical organizations in India.

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
1.	**Historical Perspective of Statistics in India** Data collection system in ancient India. Inferential Statistics and Statistical Economics before and during 4CE (Vishalaksha's contributions to inference and Kautilya's Arthashastra), Statistical System during British India, Statistical System in Independent India, Research Teaching and Training in Statistics.	10
2.	**History and Concept of Probability in ancient India** Concept of permutation and combination in ancient India, notations and rule for binomial expansion given by Pingala and others, history of probability – Rug veda, Mahabharata, Indian-Jaina philosophy.	07
3.	**Contribution of Indian Statisticians** P. C. Mahalanobis, Pandurang Vasudeo Sukhatme, Raghu Raj Bahadur, Debabrata Basu, Gopinath Kallianpur, Keshav Raghavan Nair, Calyampudi Radhakrishna Rao, Vasant Shankar Huzurbazar, J.K. Ghosh.	07
4.	**History of Indian Statistical System** Know about Ministry of Statistics and Programme Implementation (MoSPI) of Indian Government, Standing Committee on Statistics (its past and new overhaul. Historical perspective of Official Statistics in India. Overview of present Indian Statistical System: Statistical organizations and their functions – ISI, CSO, NSO.	06

Assessment:

CIA:	I	Written
	II	Written/Assignment/Viva/Presentation
ESE	ESE	Written

Reference/Text Books:

- Buchanan, F. (1807) Survey of Eastern India report submitted to the court of directors, London.
- Chaudhuri, S.B. (1964), History of Gazetteers of India, publication division, New Delhi.
- Datta AK, The concept of arithmetic mean in ancient India in 25 years gone by, ISIREA (2017):158 to 192
- Ghosh JK, Mitra, SK and Parthasarathy KR (1992), Glimpses of India's Statistical Heritage, Wiley Eastern, New Delhi.
- Ghosh, JK, Maiti P, Rao, TJ and Sinha BK (1999), Evolution of Statistics in India, international statistical review, 67,13–34
- Raju, CK "Probability in ancient India" In the handbook of philosophy of Statistics, edited by Paul Thagard Dov M. Gabbay and John Woods 7:1175 – 96.Handbook of the Philosophy of science, Elsevier, 2011

COs – POs Mapping matrix for STA ____: Foundations and Growth of Statistics in India (1-low, 2-medium, 3-high)

PO→ / CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	1	1	2	2
CO-2	3	2	3	2	2
CO-3	3	1	1	2	3
Total	**9**	**4**	**5**	**6**	**7**
Average	**3**	**1.3**	**1.7**	**2**	**2.3**

Semester VI

Course Name: Time Series Analysis & Forecasting		**Course Code: STA315/5.5STA05**
Teaching Scheme	**Examination Scheme**	**Credit :4**
Theory:4 hrs/ week	ESE: 60 Marks	**Course Type: Core**
	CIA: 20 + 20 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Linear model
2. Linear Algebra
3. Basic of stochastic process

Course Objective:

1. The main purpose is to teach the time series modeling and the concept of forecasting and future planning.

Course Outcomes: After completion of this course student will able to

1. Understand the concepts of stationarity of a time series and solve related problems.
2. Test the stationarity of a time series
3. Understand the theory related to linear and nonlinear time series models and fit an appropriate linear time series model for the data.
4. Understand the theory related to multivariate time series model VAR(1) and analyze data using VAR(1) models.
5. Use information criteria for the selection of models and forecast the value.

Course Content:

Unit	**Unit Contents**	**No. of hrs**
1.	Basics of Time series: A model building strategy, Time series and Stochastic process, Portmanteau tests for noise sequences, transformation to obtain Gaussian series, stationarity, Auto correlation, meaning and definition–causes of auto correlation-consequence of autocorrelation test for auto–correlation. Study of Time Series model and their properties using Correlogram, ACF and PACF. Yule walker equations.	15
2.	Time Series Models: White noise Process, Random walk, Unit root hypothesis, Co-integration, Dicky Fuller test unit root test, augmented Dickey – Fuller test, MA, AR, ARMA and ARIMA models, Box- Jenkins's Methodology for fitting of AR(1), AR(2), MA(1), MA(2) and ARIMA(1,1) process. Model diagnosis of fitted model and forecasting (by using software).	15
3.	Non-linear time series models, ARCH and GARCH Process, order identification, estimation and diagnostic tests and forecasting. Study of ARCH (1) properties. GARCH process for modeling volatility.	15
4.	Multivariate Time series: Introduction, Cross covariance, and correlation matrices, testing of zero cross correlation and model representation. Basic idea of Stationary vector autoregressive, Time Series with orders one, Model Structure, Granger Causality, stationarity condition, Estimation, Model checking.	15

Reference/ Text Books:

1. Box, G. E., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2015). Time series analysis: forecasting and control. John Wiley & Sons.
2. Chatfield, C. (2003). The analysis of time series: an introduction. Chapman and hall/CRC.
3. Tsay, R. S. (2005). Analysis of financial time series. John wiley & sons.
4. Tsay, R. S. (2013). Multivariate time series analysis: with R and financial applications. John Wiley & Sons.
5. Montgomery, D. C., Johnson, L. A., & Gardiner, J. S. (1990). Forecasting and time series analysis. McGraw-Hill Companies.
6. Chatfield, C. (2000). Time-series forecasting. Chapman and Hall/CRC.
7. Brockwell, P. J., & Davis, R. A. (Eds.). (2002). Introduction to time series and forecasting. New York, NY: Springer New York.
8. Chatfield, C. (2013). The analysis of time series: theory and practice. Springer.
9. Hamilton, J. D. (2020). Time series analysis. Princeton university press.
10. Cryer, J. D., & Chan, K. S. (2008). Time series analysis: with applications in R (Vol. 2). New York: Springer.

COs – POs Mapping matrix for STA315/5.5STA05: Time Series Analysis & Forecasting

(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	2	1	3
CO-2	3	3	2	1	3
CO-3	3	3	3	1	3
CO-4	3	3	3	1	3
CO-5	3	3	3	1	3
Total	**15**	**15**	**13**	**5**	**15**
Average	**3**	**3.0**	**2.6**	**1**	**3.0**

Course Name: Statistical Inference –II		**Course Code: STA 316/5.5STA06**
Teaching Scheme	**Examination Scheme**	**Credit: 4**
Theory: 4 hrs/ week	ESE:60 Marks	**Course Type: Core**
	CIA: 20 + 20 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Method of estimation and testing of hypothesis

Course Objective:

1. The purpose is to enhance the existing knowledge of Point Estimation and Testing of Hypothesis and introduce the concept of Interval Estimation.

Course Outcomes: After completion of this course student will able to

1. Obtain minimum variance unbiased estimators for various parameters of distributions.
2. Recall basic concepts of hypothesis testing.
3. Understand applications of Neyman Pearson lemma for the construction of most powerful tests
4. Implement likelihood ratio test
5. Construct best confidence intervals for population parameters.

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
1.	Statement and proof of Cramer Rao inequality. Definition of Minimum Variance Bound Unbiased Estimator (MVBUE) of $\phi(\theta)$, (statement only). Rao-Blackwell theorem, Lehmann-Scheffe theorem. Definition of MVUE, Procedure to obtain MVUE (statement only), examples. Minimum Variance Unbiased Estimator (MVUE) and Uniformly Minimum Variance Unbiased Estimator (UMVUE), complete sufficient statistic and uniqueness of UMVUE whenever it exists.	15
2.	Review of Hypothesis testing, types of hypothesis, problems of testing of hypothesis, critical region, type I and type II errors, probabilities of type I & type II errors. Power of a test, best critical region, Observed level of significance, concept of p-value, size of a test, level of significance. Definition of Most Powerful (MP) test, Neyman - Pearson (NP) lemma for simple null hypothesis against simple alternative hypothesis (with proof)- Illustrations. Power curve of a test.	15
3.	Testing for one sided and two sided alternatives: Monotone likelihood ratio properties, definition of uniformly most powerful (UMP) level α test. Statement of the theorem to obtain UMP level α test for one-sided alternative. Illustrative examples. Likelihood Ratio Test (LRT) and its properties: LRT for (i) mean and variance of normal population. (ii) The difference of two means and ratio of two variances of normal populations. Sequential probability ratio tests.	15
4.	Nonparametric Statistics: test for randomness, sign test, Wilcoxon signed-rank test, Mann-Whitney U test, Kolmogorov-Smirnov test (One sample	15

and two sample).

Reference/ Text Books:

1. George Casella, Roger L. Berger (2002), Statistical Inference, 2nd ed., Thomson Learning.
2. Mukhopadhyay P. (1996): Mathematical Statistics, New central Book Agency (P) Ltd. Calcutta.
3. Rohatgi, V.K. (1984): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.
4. Goon, Gupta & Das Gupta (1991): An Outline of Statistical Theory, Vol. II, World Press.
5. Hogg, R.V. and Craig, A.T. (1971): Introduction to Mathematical Statistics, McMillan.

COs – POs Mapping matrix for STA 316/5.5STA06: Statistical Inference –II
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	2	1	2	1
CO-2	1	1	1	3	1
CO-3	2	1	2	3	2
CO-4	1	2	2	2	2
CO-5	2	3	2	3	2
Total	**8**	**9**	**8**	**13**	**8**
Average	**1.6**	**1.8**	**1.6**	**2.6**	**1.6**

Course Name: Reliability and Survival Analysis		**Course Code: STA 317/5.5STA07**
Teaching Scheme	**Examination Scheme**	**Credit : 4**
Theory: 4 hrs/ week	ESE: 60 Marks	**Course Type: Core**
	CIA: 20 + 20 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Probability distributions

Course Objective :

To impart the concept of reliability and how statistical and probabilistic theories are applied to model and explain life of a mechanical component along with prediction of the same.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Explain and apply basic concepts of reliability and survival functions, hazard measures, and residual life.
2. Fit and interpret parametric survival models with and without censoring.
3. Analyze reliability of component–system configurations using structure functions and system models.
4. Estimate survival functions using nonparametric methods and assess their properties.
5. Apply Cox's proportional hazards model to survival data and interpret model diagnostics.

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
1	Preliminaries: Definition and concept of time, event, Reliability/Survival function, Quantiles, hazard rate, cumulative hazard function and their relation with survival function mean residual life.	**15**
2	Parametric models: Exponential, Weibull and normal and their survival characteristics. Censoring mechanisms- type I, type II and left right and interval censoring. Likelihood function under censoring and related problems, Fitting parametric models to reliability/survival data with and without censoring.	**15**
3	Component and System and its Configuration, Structure function, Series Configuration, Parallel Configuration, k out of n structure, Series – Parallel Configuration, Parallel-Series Configuration. Reliability of coherent system and characteristics, Cuts and Path, modular decomposition, Basic ideas of accelerated life testing, IFR, IFRA, NBU, DMRL, NBUE classes and their duals.	**15**
4	Empirical survival function, Actuarial estimator, Kaplan–Meier estimators and its properties. Cox's proportional hazards model with one covariate and illustration based on survival data. Partial likelihood function and Properties, residuals in Cox regression model.	**15**

Assessment:

CIA: I Written

	II	Written/Assignment/ Viva/Presentation
ESE	ESE	Written

Reference/Text Books:

1. Sinha, S. K. and Kale, B. K. (1983): Life Testing and Reliability Estimation, Wiley Eastern Limited.
2. Barlow R.E. and Proschan F. (1985): Statistical Theory of Reliability and Life testing: Holt,
3. Rinehart and Winston.
4. Lawless J.F. (1982): Statistical model and Methods of Life time data, John Willey.
5. Bain L.J. and Engelhardt (1991): Statistical Analysis of Reliability and Life testing Models, Marcel Dekker.
6. Nelson, W. (1982): Applied Life Data Analysis, John Willey.

COs – POs Mapping matrix for STA 317/5.5STA07: Reliability and Survival Analysis (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	3	3	1	3
CO-3	3	3	2	1	3
CO-4	3	3	3	1	3
CO-5	3	3	3	2	3
Total	**15**	**14**	**12**	**6**	**14**
Average	**3**	**2.8**	**2.4**	**1.2**	**2.8**

Course Name: Practical		**Course Code: STA 318/5.5STA08**
Teaching Scheme	**Examination Scheme**	**Credit : 4**
Pactical: 8 hrs/ week	ESE: 100 Marks	**Course Type: Core**

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Analyze and model time series data to generate reliable forecasts.
2. Estimate parameters and perform hypothesis testing on real datasets.
3. Fit reliability and survival models and interpret lifetime data.
4. Apply appropriate statistical software to implement analytical methods.
5. Interpret results and communicate conclusions for data-driven decisions.

The course content of this course comprise of practical exercises related to Course STA-315-317 to be executed in R-programming language.

COs – POs Mapping matrix for STA 318/5.5STA08: Practical
(1-low, 2-medium, 3-high)

PO→ CO ↓	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**
CO-1	3	3	3	1	3
CO-2	3	3	3	1	3
CO-3	3	3	3	1	3
CO-4	2	3	3	2	3
CO-5	2	2	3	1	3
Total	**13**	**14**	**15**	**6**	**15**
Average	**2.6**	**2.8**	**3**	**1.2**	**3**

VII SEMESTER

Course Name: **Probability Theory**		**Course Code: STA411/6.0STA01**
Teaching Scheme	**Examination Scheme**	Credit: **04** (3/0/2)
Theory: 3 hrs/ week	**CIA:** 20+20 Marks	**Course Type: Core**
Tutorial: 1 hrs/ week	**ESE:** 60 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Basic Probability
2. Convergence of sequence and series

Course Objective:

1. The main purpose is to introduce Probability Theory under axiomatic approach and develop further theory and concepts including the limit behaviours.

Course Outcomes: After completion of this course student will able to

1. Recognize the concept of field, sigma field, probability space, probability measure.
2. Understand the concept of convergence of sequences of random variables.
3. Apply various inequalities to solve complex statistical problems.
4. List various types of random variables.
5. Apply different probability theorems and laws for solving different mathematical problems.

Unit 1 **20**

Classes of sets, field and sigma fields, limit of sequences of subsets, sigma field generated by a class of subsets, Borel field, Borel sigma field. Measure, probability measure, probability space, properties of probability measure-continuity, mixture of probability measures. Lebesgue and Lebesgue - Steltjes measures on R.

Unit 2 **15**

Distribution functions of discrete rvs, continuous and mixed type rv, decomposition of a df. Expectation of rv and its properties. Properties of Expectations. Characteristic function, simple properties.Inversion theorem and uniqueness property. Inequalities: Jensen's, Markov's, Chebychev's, Holder's and Lyapounov inequalities with its applications.

Unit 3 **15**

Independence of two events and n(>2) events, sequence of independent events. Monotone convergence theorem, Fatous Lemma, Dominated Convergence theorem, Borel - Cantelli Lemma, and their applications. Convergence of sequence of random variables, Convergence in distribution, continuity theorem (Statement only), Almost sure convergence, a characterizing property, convergence in probability, uniqueness of limit, Yule Slutsky results and preservation under continuous transform.(Statements only), convergence in r^{th} mean, interrelationships.

Unit 4 **10**

Weak and Strong laws of large numbers, Kolmogorov's three series theorem for almost sure convergence (Statement only), Demoivre-Laplace, Liaponove's, Lindeberg-Feller theorems on CLT (Statement only).

Reference/ Text Books:

1. Rao, B. P. (2009). A first course in probability and statistics. World Scientific.
2. Meyer, P.A. (1970) An Introduction to Probability and Its Applications. PHI
3. Rohatgi V.K & A.K. MD. Ehsanes Saleh (2001): An Introduction to Probability Theory and Mathematical Statistics, 2nd. John Wiley and Sons.
4. Allan Gut (2011) Probability : A Graduate Course. Springer

COs – POs Mapping matrix for STA411/6.0STA01: Probability Theory

(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	2	2
CO-2	3	3	2	1	2
CO-3	3	3	2	1	3
CO-4	3	2	1	1	2
CO-5	3	3	2	1	3
Total	**15**	**13**	**8**	**6**	**12**
Average	**3**	**2.6**	**1.6**	**1.2**	**2.4**

Course Name: **Distribution Theory**		**Course Code: STA412/6.0ST02**
Teaching Scheme **Theory:** 3 hrs/ week **Tutorial:** 1 hrs/ week	**Examination Scheme** **CIA:** 20+20 Marks **ESE:** 60 Marks Total: 100 Marks	**Credit: 4** **Course Type: Core**

Course Pre-requisites: Student must have knowledge of

1. Statistical inference
2. Probability distributions.

Course Objective:

1. To introduce students to important continuous and non-central probability distributions and their practical applications.
2. To develop understanding of compound, truncated, mixture, and generated families of distributions used in modeling complex data.
3. To build conceptual clarity on order statistics, extreme value theory, and their role in statistical inference.

Course Outcomes: After completion of this course student will able to

1. Identify and apply properties of common and non-central continuous distributions in practical contexts.
2. Analyze compound, truncated, mixture, and generated families of distributions.
3. Derive and interpret distributions of order statistics and extreme values for samples.
4. Analyze bivariate distributions and obtain marginal and conditional distributions.
5. Visualize and interpret bivariate normal densities for joint behavior of random variables.

Unit 1 **15**

Weibull, Pareto, lognormal, Laplace, Cauchy, logistic, Rayleigh distribution their properties and applications. Non-central chi-square, t and F distributions. Generalized error distribution and its applications.

Unit 2 **15**

Compound, truncated and mixture distributions. Convolutions of two distributions. Beta Generated family of Distribution, Gamma generated Family of distribution.

Unit 3 **15**

Order statistics: their distributions and properties. Joint, marginal and conditional distribution of order statistics. The distribution of sample range and sample median. Extreme values and their asymptotic distribution (statement only) with applications.

Unit 4 **15**

Bivariate distributions, Multinomial distribution, Marshall-Olkin bivariate exponential distribution, bivariate normal distribution, marginal and conditional distribution, mgf, some properties. Plotting of bivariate normal density function.

Reference/Text Books:

1. Berger, J. O. (2013). Statistical decision theory and Bayesian analysis. Springer Science &

Business Media.
2. Bernardo, J. M., & Smith, A. F. (2009). Bayesian theory (Vol. 405). John Wiley & Sons.
3. Robert, C. P. (2007). The Bayesian choice: from decision-theoretic foundations to computational implementation (Vol. 2). New York: Springer.
4. Ferguson, T. S. (2014). Mathematical statistics: A decision theoretic approach (Vol. 1). Academic press.
5. Casella, G., & Berger, R. L. (2021). Statistical inference. Cengage Learning.
6. Rohatgi, V. K., & Saleh, A. M. E. (2015). An introduction to probability and statistics. John Wiley & Sons.
7. Kotz, S., Balakrishnan N. and Johnson N. L. (2000): Continuous Multivariate Distributions, Volume 1, Models and Applications, John Wiley & Sons.

COs – POs Mapping matrix for STA412/6.0STA02: Distribution Theory (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	1	1	2
CO-2	3	3	2	1	2
CO-3	3	3	2	1	3
CO-4	3	3	2	1	3
CO-5	2	3	1	1	3
Total	**14**	**15**	**8**	**5**	**13**
Average	**2.8**	**3.0**	**1.6**	**1**	**2.6**

Course Name: Sampling Theory		**Course Code: STA413/6.0STA03**
Teaching Scheme	**Examination Scheme**	**Credit: 4**
Theory: 3 hrs/ week	**CIA:** 20+20 Marks	**Course Type: Core**
Tutorial: 1 hrs/ week	**ESE:** 60 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Descriptive Statistics
2. Probability and probability distributions
3. Statistical Inference
4. Knowledge of R

Course Objective: After successfully completing this course, students should ordinarily expect to be able to:

1. Describe different types of population approaches.
2. Describe different methods of sampling designs.
3. Describe different methods of estimation under double sampling scheme.
4. Describe non-sampling errors in a sample survey.

Course Outcomes: After completion of this course student will able to

1. Understand the concepts of super population, various standard sampling designs and solve problems related to them.
2. Understand the concepts of unequal probability sampling, PPS sampling (PPSWOR/WR) and solve problems related to them.
3. Understand the concepts of double sampling, methods of estimation under double sampling and solve problems related to them.
4. Understand the concepts of cluster sampling, two-stage sampling and solve problems related to them.
5. Understand the non-sampling errors and handling the non-response in sample surveys and solve related problems.

Unit 1 **15**

Fixed population and super-population approaches. Distinct features of finite population sampling, Review of basic methods of simple random sampling and stratified random sampling. Post stratification, Deep stratification, Controlled sampling, estimators along with basic statistical properties, exercises.

Unit 2 **17**

Unequal probability sampling: PPSWR/WOR methods (including Lahiri's scheme) and Des-Raj estimator, Murthy estimator (for n=2). Horvitz Thompson Estimator of finite population total/mean, Expression for Variance (HTE) and its unbiased estimator, Issue of non-negative variance estimation, exercises.

Unit 3 **13**

Review of the use of supplementary information for estimation, concept of double sampling,

two-phase sampling, stratification estimator, ratio, product and regression estimators with their properties under double sampling, Some unbiased ratio type estimators for population mean, exercises.

Unit 4 **15**

Review of cluster sampling (equal cluster size), cluster sampling (unequal cluster size), concept of two-stage sampling, non-sampling error with special reference to non-response problems and its treatments, exercises.

Reference/ Text Books:

1. Cochran, W.G. (2007): Sampling Techniques , Third Edition, Wiley India Pvt. Ltd., New Delhi.
2. Murthy, M. N. (1977): Sampling Theory and Methods, Statistical Publishing Society, Kolkata.
3. Cochran, W.G.(2007): Sampling Techniques , Third Edition, Wiley India Pvt. Ltd., New Delhi. 2. Murthy, M. N. (1977): Sampling Theory and Methods, Statistical Publishing Society, Kolkata.
4. Singh, D. and Chaudhary, F. S. (1986): Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.
5. RaghunathArnab (2017): Survey Sampling Theory and Applications, Academic Press, Elsevier.
6. Mukhopadhyay P (2008): Theory and methods of survey sampling. Prentice-Hall of India, New Delhi.
7. Latpate, R., Kshirsagar, J.,Gupta V. and Chandra, G. (2021). Advanced Sampling Methods, Springer.

E-Resources:

1. https://nptel.ac.in/courses
2. http://mospi.nic.in/

COs – POs Mapping matrix for STA413/6.0STA03: Sampling Theory (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	3	1	3
CO-2	3	3	3	1	3
CO-3	3	3	3	1	3
CO-4	3	3	3	1	3
CO-5	2	3	3	1	3
Total	**14**	**15**	**15**	**5**	**15**
Average	**2.8**	**3.0**	**3.0**	**1**	**3.0**

VIII SEMESTER

Course Name: Theory of Estimation and Testing of Hypothesis		**Course Code: STA416/6.0STA06**
Teaching Scheme	**Examination Scheme**	**Credit 4**
Theory: 3 hrs/ week	ESE: 60 Marks	**Course Type: Core**
Tutorial: 1 hrs/ week	CIA: 40 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Standard probability distribution

Course Objective:

4. The main purpose is to make an individual understand basic theoretical knowledge about fundamental principles of statistical inference.

Course Outcomes: After completion of this course student will able to

1. Recognize different methods of parameter estimation
2. Recall various properties of estimators
3. Apply different statistical test procedures for different testing of hypothesis problems
4. Compare different statistical test through power comparison.
5. Analyze various real life data sets using tests of hypothesis

Course Content:

Unit	**Unit Contents**	**No. of Hrs**
	Criteria of a good estimator: unbiasedness, consistency, efficiency and sufficiency. Concept of mean squared error. Fisher-Neyman factorization theorem, Family of distributions admitting sufficient Statistic.	
1.	Point estimation, Maximum likelihood method (MLE), moments, Least squares method. Method of minimum chi-square and percentiles. Properties of maximum likelihood estimator (with proof). Successive approximation to MLE, Method of scoring and Newton-Raphson method.	10
2.	Cramer-Rao inequality and its attainment, Cramer-Huzurbazar theorem (statement only), Completeness and minimal sufficient statistic, Ancillary statistic, Basu theorem, Uniformly minimum variance unbiased estimator (UMVUE). Rao-Blackwell and Lehmann-Scheffe theorems and their applications, Review of convergences of random variables and their implications, Delta method and its application, Asymptotic efficiency and asymptotic estimator, consistent asymptotic normal (CAN) estimator.	15
3.	Statistical Hypothesis, critical region, types of errors, level of significance, power of a test, Test function, Randomized and non-randomized tests, Most powerful test and Neyman-Pearson lemma. MLR family of distributions, unbiased test. Uniformly most powerful test. Uniformly most powerful unbiased test. Likelihood ratio test with its properties.	10
4.	Sequential estimation and testing, SPRT, OC curve, ASN function, Wald's equation and problems.	10
5.	Confidence interval, confidence level, construction of confidence intervals	15

using pivots, Determination of confidence intervals based on large and small samples, uniformly most accurate one sided confidence interval and its relation to UMP test for one sided null against one sided alternative hypotheses.

Assessment:

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE	ESE	Written

Reference/ Text Books:

1. Casella, G., & Berger, R. L. (2021). Statistical inference. Cengage Learning.
2. Mukhopadhyay, P. (2012). Theory of Probability. New Central Book Agency.
3. Rao, C. R., Rao, C. R., Statistiker, M., Rao, C. R., & Rao, C. R. (1973). Linear statistical inference and its applications (Vol. 2, pp. 263-270). New York: Wiley.
4. Rohatgi, V.K. (1976): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern
5. Goon, A. M., Gupta, M. K., & Dasgupta, B. (2000). An Outline of Statistical Theory , Vol. II.
6. Hogg, R. V., & Craig, A. T. (1965). Introduction To Mathematical Statistics 2. Auflage. Macmillan.
7. Kale, B. K. (2005). A first course on parametric inference. Alpha Science Int'l Ltd..
8. Lehmann, E. L., & Lehmann, E. L. (1986). Testing statistical hypotheses (Vol. 2). New York: Wiley.

COs – POs Mapping matrix for STA416/6.0STA06: Theory of Estimation and Testing of Hypothesis
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	2	1	2
CO-2	3	2	1	1	2
CO-3	3	3	3	1	3
CO-4	3	3	2	1	3
CO-5	2	3	3	1	3
Total	**14**	**13**	**11**	**5**	**13**
Average	**2.8**	**2.6**	**2.2**	**1**	**2.6**

Course Name: Regression Analysis		**Course Code: STA 417/6.0STA07**
Teaching Scheme	**Examination Scheme**	**Credit: 4**
Theory: 3 hrs/ week	ESE: 60 Marks	**Course Type: Core**
	CIA: 20+20 Marks	
Practical: 2 hrs/ week	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Correlation
2. Simple linear regression
3. Linear algebra
4. Exponential family of distributions

Course Objective:

1. The main purpose is to provide the theoretical foundations for the Linear Estimation Theory and Regression Analysis.

Course Outcomes: After completion of this course student will able to

1. Develop the linear predictive models and their extensions in nonlinear models, generalized models.
2. Diagnose and apply corrections to some problems with the generalized linear model found in real data.
3. Address practical problems and give a sound scientific interpretation to the results.
4. Assess the model using standard criterions.
5. Use standard statistical software to develop models and analyze data that arise from different fields.

Course Content:

Unit	**Unit Contents**	**No. of hrs**
1.	Theory of linear estimation, estimable function, multiple regression model, least squares estimator and its properties, variance and covariance of least squares estimator, BLUE, estimation space, error space, Gauss-Markov theorem in linear estimation. Confidence interval estimation, prediction interval, distribution of quadratic forms for normal variables: related theorems (statements only), hypothesis testing for model for general linear hypothesis, testing of individual regression coefficients. Residual analysis: different types of residuals, residual plots. Dummy variables and their use in regression analysis.	15
2.	Multicollinearity: Consequences, detection and remedies, ridge regression. Variable Selection Procedures: R-square, adjusted R-square, Mallows' Cp, forward, backward and stepwise selection methods, AIC, BIC. Variance stabilizing transformations.	15
3.	Fundamental concept of generalized linear model (GLM), exponential family of random variables. Link functions such as Logit, Probit, binomial, inverse Gaussian, gamma. Nonlinear models, ML estimation in nonlinear models. Large sample tests about parameters, goodness of fit, analysis of deviance.	15

4.	Variable selection: AIC and BIC. Logistic regression: logit, probit and cloglog model for dichotomous data with single and multiple explanatory variables, ML estimation, large sample tests about parameters. Hosmer-Lemeshow test, ROC curve. Poisson regression: ML and Quasi-likelihood estimation of parameters, testing significance of coefficients, goodness of fit test.	15

Internal Assessment:

CIA:	I	Written
	II	Written/Assignment/ Viva/Presentation
ESE	ESE	Written

Reference/ Text Books:

1. Montgomery, D. C., Peck, E. A., & Vining, G. G. (2021). Introduction to linear regression analysis. John Wiley & Sons.
2. Kutner, M. H., Nachtsheim, C. J., Neter, J., & Wasserman, W. (2004). Applied linear regression models (Vol. 4, pp. 563-568). New York: McGraw-Hill/Irwin.
3. Hosmer Jr, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). Applied logistic regression (Vol. 398). John Wiley & Sons.
4. McCullagh, P., & Nelder, J. A. (2019). Generalized linear models. Routledge.

E-Resources:

1. https://nptel.ac.in/courses/111105042

COs – POs Mapping matrix for STA 417/6.0STA07: Regression Analysis
(1-low, 2-medium, 3-high)

PO→ / CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	2	1	3
CO-2	3	3	3	1	3
CO-3	2	3	2	1	3
CO-4	3	3	2	1	3
CO-5	2	3	2	1	3
Total	**13**	**15**	**11**	**5**	**15**
Average	**2.6**	**3.0**	**2.2**	**1**	**3.0**

Course Name: MINOR PROJECT		**Course Code: STA 431**
Teaching Scheme	**Examination Scheme**	**Credit Allotted: 02**
Practical: 12		**Course Type: RP**
Total: 12	Total: 100 Marks	

Course Objectives:

1. To identify real-world statistical problems and formulate suitable objectives for investigation.
2. To develop skills in collecting, organizing, and managing primary or secondary data ethically.
3. To apply appropriate statistical methods, tools, and techniques to analyze real data.
4. To enhance report-writing and presentation skills for effective communication of findings.
5. To cultivate independent work habits, responsibility, and project management within timelines.

Course Outcome: Upon successful completion of this course, the student will be able to:

1. Identify a real-world problem and formulate suitable objectives for a statistical case study.
2. Collect primary or secondary data ethically and organize it for analysis.
3. Apply appropriate statistical methods and tools to analyze the case study data.
4. Prepare a well-structured project report and present findings effectively.
5. Work independently and responsibly to complete the project within given timelines.

Guidelines for the Minor project

a. **Project duration:** Students may start the work related to minor project after first semester.
b. **Project Guide:** Student have to conduct a case study and if required collect the data or use secondary data to perform the case study. As such students can consult with all available teachers about the conduct of Case study. No exclusive teacher will be assign.
c. **Project report:** Project report should be submitted in typed form in hard copy form within the time as stipulated by the Department.
d. Faculty Assignment: A faculty member will be assign duty for smooth conduct of this course.
e. **Project evaluation:** Project evaluation will be based on
    1. Continuous evaluation –I 20 Marks awarded by the Teacher's panel.
    2. Project report submission- 20 marks.
    3. Viva-voce and final presentation - 60 marks awarded by Teacher's panel..

COs – POs Mapping matrix for STA 431: MINOR PROJECT
(1-low, 2-medium, 3-high)

PO→ CO ↓	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**
CO-1	2	3	2	1	3
CO-2	1	2	3	1	3
CO-3	2	3	3	1	3
CO-4	1	2	2	2	3
CO-5	1	1	2	2	3
Total	**7**	**11**	**12**	**7**	**15**
Average	**1.4**	**2.2**	**2.4**	**1.4**	**3.0**

Course Name: Stochastic Processes		Course Code: STA418/6.0STA08
Teaching Scheme	**Examination Scheme**	**Credit 04**
Theory: 3 hrs/ week Tutorial: 1 hrs/ week	CIA I & II = 20+20 marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Random variables
2. Conditional probability
3. Generating functions

Course Objective:

1. The main objective of the paper is to provide theoretical foundations of Stochastic Processes and to introduce different Stochastic/Random Processes and their applications.

Course Outcomes:

1. Differentiate between various types of stochastic processes.
2. Understand Markovian property
3. Evaluate higher transition probabilities.
4. Apply stochastics models in business problems.
5. Recognize applications of branching, Brownian and renewal processes

Course Content:

Unit No.	Unit Contents	No. of Hrs
1.	Definition of stochastic process, classification of stochastic processes according to state space and time domain, finite dimensional distributions. Examples of various stochastic processes. Definition of Markov chain. Examples of Markov chains, Formulation of Markov chain models, initial distribution, transition probability matrix, Chapman-Kolmogorov equations, calculation of *n*-step transition probabilities. Simulation of Markov Chain.	15
2.	Classification of states, irreducible Markov chain, period of the state, random walk and Gambler's ruin problem, first entrance theorem, first passage time distribution. Long-Run proportions and limiting probabilities, relation with mean recurrence time, stationary distribution.	15
3.	Continuous time Markov Chain: Poisson process and related inter-arrival time distribution, compound Poisson process, Pure birth process, pure death process, birth and death process, problems, Renewal processes, Elementary renewal theorem (statement only) and its applications	15
4.	Galton-Watson Branching process. Generating functions and its properties, moments. Probability of ultimate extinction. Distribution of population size and association results. Simulation of branching process. Martingales, stopping times. Introduction to Brownian motion process and its basic properties.	15

Reference/ Text Books:

1. Kulkarni, V. G. (2016). Modeling and analysis of stochastic systems. Chapman and Hall/CRC.
2. Medhi J. (2009). Stochastic Process. New Age International Publications.
3. Cinlar E. (2013). Introduction to Stochastic Process. Courier Corporation.
4. Ross S. (1996): Stochastic Processes. Wiley.
5. Hoel, P. G., Port, S. C., & Stone, C. J. (1986). Introduction to stochastic processes. Waveland Press.
6. Pinsky, M., & Karlin, S. (2010). An introduction to stochastic modeling. Academic press.

COs – POs Mapping matrix for STA418/6.0STA08: Stochastic Processes (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	3	1	1	2
CO-3	3	3	2	1	2
CO-4	2	3	2	1	3
CO-5	3	3	2	1	3
Total	**s**	**14**	**8**	**5**	**12**
Average	**2.8**	**2.8**	**1.6**	**1**	**2.4**

Course Name: Design and Analysis of Experiments		**Course Code: STA419/6.0STA09**
Teaching Scheme	**Examination Scheme**	**Credit 03**
Theory: 2 hrs/ week	CIA I & II = 20+20 marks ESE: 60 Marks	
Practical: 2 hrs/ week	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Linear algebra
2. Basic design of experiments

Course Objective:

1. Enable to plan, design and conduct experiments efficiently and effectively, and analyze the resulting data to obtain objective conclusions.

Course Outcomes: After completion of this course student will able to

1. Understand the potential practical problems and applications of design of experiments in various fields.
2. Build a deeper understanding, and tools for analysis of experiments.
3. Describe how the analysis of the data from the experiment should be carried out.
4. Use a statistical computing packages to analyze real-life data.
5. Appreciate the advantages and disadvantages of a design for a particular experiment.

Course Content:

Unit No.	**Unit Contents**	**No. of Hrs**
1.	Basic principle of experimental design, overview of RBD, CRD and LSD. Purpose of analysis of covariance. Practical situations where analysis of covariance is applicable. Model for analysis of covariance in CRD and RBD. Estimation of parameters (derivations are not expected). Preparation of analysis of covariance (ANOCOVA) table, test for $\beta = 0$, test for equality of treatment effects (computational technique only).	15
2.	Contrasts, orthogonal contrasts, Scheffé's method for comparing contrasts; Comparing pairs of treatment means: Tukey's test, Fisher least significant difference method, comparing treatment means with a control. General theory of intra block analysis of block design, connectedness and balancing block design, incomplete block design, intra block analysis of BIBD and its properties.	15
3.	Concepts of factorial designs, main effects, and interaction effects, The two-factor factorial design and its analysis using fixed effect model, The general factorial design, Analysis of replicated and unreplicated 2^k full factorial designs. Blocking and confounding in a 2^k factorial design. Construction and analysis of 2^{k-p}fractional factorial designs and their alias structures.	15
4.	The 3^k full factorial design and its analysis using fixed effect model. Response surface methodology: the method of steepest ascent, analysis of the response surface using first and second order models, characterizing the response surface, ridge systems, multiple responses, designs for fitting response surfaces: simplex design, central composite design (CCD), The concepts of nested and split-plot	15

designs.

Reference/ Text Books:

1. Montgomery, D. C. (2017). Design and analysis of experiments. John Wiley & sons.
2. Hinkelmann, K., & Kempthorne, O. (2007). Design and analysis of experiments, volume 1: Introduction to experimental design (Vol. 1). John Wiley & Sons.
3. Wu, C. J., & Hamada, M. S. (2011). Experiments: planning, analysis, and optimization. John Wiley & Sons.
4. Dean, A., & Voss, D. (Eds.). (1999). Design and analysis of experiments. New York, NY: Springer New York.

E-Resources:

http://www.ru.ac.bd/stat/wp-content/uploads/sites/25/2019/03/502_06_Montgomery-Design-and-analysis-of-experiments-2012.pdf

COs – POs Mapping matrix for STA419/6.0STA09: Design and Analysis of Experiments (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	2	3	1	3
CO-2	3	3	3	1	3
CO-3	3	3	3	1	3
CO-4	2	3	2	1	3
CO-5	3	3	2	1	3
Total	**13**	**14**	**13**	**5**	**15**
Average	**2.6**	**2.8**	**2.6**	**1**	**3.0**

Semester IX

Course Name: Multivariate Time Series Analysis and Forecasting		**Course Code : STA511/6.5STA01**
Teaching Scheme	**Examination Scheme**	**Credit Allotted: 04**
Theory: 3 hours/ week	End Semester Examination: 60 Marks	**Course Type: Core**
Practical: 2 hours	Internal Assessment: 20 + 20 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Linear model
2. Linear Algebra
3. Basic of stochastic process

Course Objective:

1. The main purpose is to teach the multivariate time series modeling and the concept of forecasting and future planning.

Course Outcomes: After completion of this course student will able to

1. Understand the concepts of stationarity of a multiple time series and solve related problems.
2. Understand the theory related to multivariate time series models and fit an appropriate time series model for the data.
3. Understand the theory related to multivariate time series model VAR(1) and analyze data using VAR(1) models.
4. Understand the theory related to multivariate time series model VECM and analyze data by using this model.
5. Generate reasonable forecast values and make concise decisions based on forecasts obtained.

Course Content:

Unit No.	**Unit Contents**	**No. of Hrs**
1.	Overview of Univariate time series analysis, Multivariate time series, definition, Multivariate Time series: Introduction, Cross covariance, and correlation matrices, testing of zero cross correlation. Introduction of Vector Moving Average (VMA), Vector Autoregressive (VAR) and Vector Autoregressive Moving Average (VARMA).	15
2.	Vector autoregressive (VAR): Introduction, Model Structure, Assumptions and Properties. Structural analysis of with VAR, Estimation of VAR (1), Testing for Causality.	15
3.	Vector error correction model, estimating VECMs, Testing of Granger- Causality, Impulse Response analysis, Lag Selection, model diagnostics.	10
4.	Forecasting, Basic steps in foresting, forecasting tools, forecasting resources, forecasting methods. Forecasting measures. Advance forecasting models (AR, MA, ARMA, ARIMA, ARCH, GARCH, VAR, Panel VAR), problem and challenges with long term forecast, Judgmental forecasting and adjustment. Use of forecasting method in practice.	20

Reference/ Text Books:

1. Box, G. E., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2015). Time series analysis: forecasting and control. John Wiley & Sons.
2. Chatfield, C. (2003). The analysis of time series: an introduction. Chapman and hall/CRC.

3. Tsay, R. S. (2005). Analysis of financial time series. John wiley & sons.

4. Tsay, R. S. (2013). Multivariate time series analysis: with R and financial applications. John Wiley & Sons.
5. Montgomery, D. C., Johnson, L. A., & Gardiner, J. S. (1990). Forecasting and time series analysis. McGraw-Hill Companies.
6. Chatfield, C. (2000). Time-series forecasting. Chapman and Hall/CRC.
7. Brockwell, P. J., & Davis, R. A. (Eds.). (2002). Introduction to time series and forecasting. New York, NY: Springer New York.
8. Cryer, J. D., & Chan, K. S. (2008). Time series analysis: with applications in R (Vol. 2). New York: Springer.

COs – POs Mapping matrix for STA511/6.5STA01: Multivariate Time Series Analysis and Forecasting
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	2	1	3
CO-2	3	3	3	1	3
CO-3	3	3	3	1	3
CO-4	3	3	3	1	3
CO-5	3	3	3	1	3
Total	**15**	**15**	**14**	**5**	**15**
Average	**3**	**3**	**2.8**	**1**	**3**

Course Name: Multivariate Analysis		**Course Code: STA512/6.5STA02**
Teaching Scheme	**Examination Scheme**	**Credit 04**
Theory: 3 hrs/ week	CIA I & II = 20+20 marks ESE: 60 Marks	
Practical: 2 hrs/ week	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Probability and probability distributions
2. Statistical Inference
3. Linear Algebra and linear model

Course Objective: After successfully completing this course, students should ordinarily expect to be able to:

1. Understand the main features of multivariate data.
2. Understand the characteristics of multivariate quantitative research
3. Understand the principles and characteristics of multivariate statistical techniques and methods efficiently and effectively.

Course Outcomes: After completion of this course student will able to

1. Describe basics of multivariate data and understand properties of multivariate normal distribution
2. Describe Wishart distribution, applications of Hotelling's T^2 statistics and Mahalanobis D^2 statistic.
3. Implement discriminant analysis, classification problems, principal components analysis, and canonical correlation analysis effectively.
4. Demonstrate knowledge and understanding of the basic idea behind factor analysis and cluster analysis effectively.
5. Perform classification of multivariate data.

Course Content:

Unit No.	**Unit Contents**	**No. of Hrs**
1.	Multivariate distribution function, marginal and conditional distribution, sample mean vector, sample dispersion matrix, correlation matrix, covariance matrix, exercises. Multivariate normal distribution and its properties, random sampling from multivariate normal distribution, maximum likelihood estimators of parameters, distribution of sample mean vector, exercises.	20
2.	Wishart distribution and its properties. Hotelling's T^2 and its applications. Hotelling's T^2 statistic as a generalization of square of Student's statistic. Distance between two populations, Mahalnobis D2 statistic and its relation with Hotelling's T^2 statistic, Distribution of multiple correlation coefficients, their maximum likelihood estimators (MLE). exercises.	15
3.	Discriminant analysis, classification problem, exercises.	10
4.	Principle component analysis, Factor Analysis, Canonical correlation, Cluster Analysis, Exercises.	15

Reference/ Text Books:

1. Anderson, T. W. (1984): Introduction to Multivariate Analysis, John Wiley

2. Fang, K., Kotz, S., Ng K. W. (1990): Symmetric Multivariate and Related Distributions, Chapman and Hall
3. Härdle, W. K. and Simar, L. (2012): Applied Multivariate Statistical Analysis, Springer, New York
4. Johnson, R.A. and Wichern, D.W. (2007): Applied Multivariate Statistical Analysis, 6th Ed., Pearson Education.

5. Kshirsagar, A. M. (1983): Multivariate Analysis, Marcel Dekker
6. Manly, B. F. J., (2004): Multivariate Statistical Methods - A primer, Chapman and Hall / CRC Florida
7. Morrison, D.F. (1990): Multivariate Statistical Methods, McGraw Hill Co.
8. Timm, N. H. (2002): Applied Multivariate Analysis, Springer, New York

E-Resources:

1. https://onlinecourses.swayam2.ac.in/cec20_ma17/preview

COs – POs Mapping matrix for STA512/6.5STA02: Multivariate Analysis
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	3	2	1	3
CO-3	3	3	3	1	3
CO-4	3	3	2	1	3
CO-5	2	3	3	1	3
Total	**14**	**14**	**11**	**5**	**14**
Average	**2.8**	**2.8**	**2.2**	**1**	**2.8**

Course Name : Survival Analysis		**Course Code: STA513/6.5STA03**
Teaching Scheme	**Examination Scheme**	**Credit : 04**
Theory: 3 hrs/ week Practical: 2 hrs/week	CIA I & II = 20+20 marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Distribution theory

Course Objective:

The main objective of this paper is to introduce different concepts and applications of survival analysis.

Course Outcome:

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

1. Understand the need of life time distributions and their properties.
2. Identify the different type of censoring.
3. Estimate parameters in presence of censoring.
4. Implement different parametric and nonparametric estimators for estimating survival function.
5. Analyze the lifetime event data.

Course Content

Unit No.	**Unit Contents**	**No. of Hrs**
1	Survival Characteristics and Parametric Models: Survival function, quantiles, hazard rate, cumulative hazard function, and mean residual life, Parametric models for study of event time data: Exponential, Weibull, extreme value, gamma, Pareto, logistic, log-logistic, normal, log–normal and mixture models - their survival characteristics.	**15**
2	Parametric Inference: Longitudinal studies. Censoring mechanisms- type I, type II and left right, Progressive censoring and interval censoring. Likelihood function under censoring and estimation. Tests based on LR, MLE.	**15**
3	Nonparametric Inference: Actuarial and Kaplan–Meier estimators. Treatment of ties. Self-consistency property and asymptotic properties of K–M estimator (statement). Point wise confidence interval for S(t). Nelson-Aalen estimator of cumulative hazard function and estimation of S(t) based on it. Two–sample methods. Comparison of survival functions: Log rank and Tarone-Ware tests.	**15**
4	Semi-parametric Inference: Explanatory variables- factors and variates. Cox proportional hazards model. The partial likelihood and estimation of regression coefficients and their standard errors. Breslow's estimator, Statement of asymptotic properties of the estimator. Confidence interval for regression coefficients. Wald, Rao and likelihood tests for β. Accelerated life model. Model selection criteria and comparison of nested models (-2logL, AIC, BIC). Using information on prognostic variables in a competing risks model. Concept of frailty. Introduction to various frailty models and its applications.	**15**

Reference

1. Cox, D.R. and Oakes, D. (1984). Analysis of Survival Data, Chapman and Hall.
2. Deshpande, J.V. and Purohit S.G. (2005). Life Time Data: Statistical Models and Methods, Word Scientific.
3. Duchateau, L. and Johnson, P. (2008). The Frailty Model. Springer: New York.
4. Gross A.J. and Clark, V. A. (1975) Survival Distributions: Reliability Applications in the Biomedical Sciences, John Wiley and Sons.
5. Hanagal, D. D. (2011). Modeling Survival Data Using Frailty Models. CRC Press: New York.
6. Wienke, A. (2011). Frailty Models in Survival Analysis, CRC Press: New York.

COs – POs Mapping matrix for STA513/6.5STA03: Survival Analysis
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	2	2	1	2
CO-3	3	3	3	1	3
CO-4	3	3	3	1	3
CO-5	2	3	3	1	3
Total	**14**	**13**	**12**	**5**	**13**
Average	**2.8**	**2.6**	**2.4**	**1**	**2.6**

Semester X

Course Code :	**STA 531/6.5STA81**
Course Name :	**Major Research Project (in Industry or in Academia)**
Credits :	**20**

Course Objectives:

1. To expose students to real-world research problems in industry or academia using statistical methods.
2. To develop the ability to design, plan, and execute an independent research project.
3. To strengthen skills in data collection, statistical analysis, and interpretation using appropriate software tools.
4. To enhance problem-solving, critical thinking, and scientific reasoning abilities.
5. To build professional communication skills through technical report writing and oral presentation.

Course Outcome:

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

1. Identify a real-world research problem and formulate clear statistical objectives.
2. Design and implement an appropriate methodology for data collection and analysis.
3. Apply statistical tools and software to analyze real data and interpret results scientifically.
4. Work independently and collaboratively to manage and execute a long-term research project.
5. Communicate research findings effectively through a written report and oral presentation.

Guidelines for project

a. **Project duration:** Students may start preliminary work related to their project after third semester.

b. **Project Guide:** Teachers from the Department of Statistics and/or organization where student is going to visit for field work or training. For outside organization, there will be one internal teacher who monitor the progress of the student. Each project student have to work 20 hours per week in the department or work place (in case of industrial) throughout the IV semester.

c. **Project Topic:** Students in consultation with the guide will decide project topic. The modification on the title may be permitted after the pre-presentation as advised during the seminar in consultation with the supervisor. Project work may be carried out in a group of students depending upon the depth of fieldwork/problem involved.

d. **Project report:** Project report should be submitted in typed form in hard bound within the time as stipulated by the Department.

e. Project Evaluation: The evaluation of Major Project will comprise of two components Internal and External.

Internal Component will further comprise of two subcomponents

- Continuous evaluation of the work – 30 Marks awarded by supervisor
- Project report and final presentation – 20 marks by all faculty member of the department.

External Component

The External expert from outside University/Institute will conduct a Viva-voce and final presentation of all the students and award a maximum of 50 marks.

COs – POs Mapping matrix for STA 531/6.5STA81: Major Research Project (in Industry or in Academia)
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	2	1	2
CO-2	3	3	3	1	3
CO-3	3	3	3	1	3
CO-4	2	2	2	3	3
CO-5	2	2	2	3	3
Total	**13**	**12**	**12**	**9**	**14**
Average	**2.6**	**2.4**	**2.4**	**1.8**	**2.8**

List of Electives for Semester VIII

Course Name: National Development Statistics (Elective)		Course Code: STA481/6.0STA31
Teaching Scheme	**Examination Scheme**	**Credit 03**
Theory: 3 hrs/ week	End Semester Examination: 60 Marks Internal Assessment: 20 + 20 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Normal, Chi-square, t, and F distributions, t-test

Objective:

The main objective is to make individual understand the significance and role of statistics in national development.

Learning Outcome:

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

1. Understand the concept of Economic development parameters.
2. Differentiate the population growth of developed and developing countries.
3. Apply different techniques of poverty measurement.
4. Know various institutions responsible for the collection of data in India.
5. Understand various issues in the measurement of poverty.

Course Content

Unit No.	Unit Contents	No. of Hrs
1	Economic development: Growth in per capital income and distributive justice, Indices of development, Human Development index, quality of life. Estimation of national income-product approach, income approach and expenditure approach	12
2	Population growth in developing and developed countries, Population projection using Leslie matrix, Labour force projection.	10
3	Poverty measurement-different issues, measures of incidence and intensity, combined measures e.q. indices due to Kakwani, Sen etc.	13
4	MOSPI- Statistical System of India: NSSO, CSO, NSSTA, NITI Ayoge, Different Institutions and committees are responsible for planning and execution of National Building.	10

References

1. Chatterjee, S.K.: Quality of life.
2. Chaubey, P. K.: Poverty Analysis, New Age International (P) Limited, Publishers. New Delhi.
3. Human Development Annual Report.
4. Sen, Amartya.: Poverty and Famines, Oxford University Press.
5. CSO. National Accounts Statistics- Sources and Health.
6. UNESCO: Principles of Vital Statistics Systems.

COs – POs Mapping matrix for STA481/6.0STA31: National Development Statistics
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	2	1	1	2
CO-3	3	3	2	1	3
CO-4	3	1	1	2	3
CO-5	3	2	1	2	3
Total	**15**	**10**	**6**	**7**	**13**
Average	**3**	**2.0**	**1.2**	**1.4**	**2.6**

Course Name: Computer Intensive Statistical Methods (Elective)		**Course Code: STA482/6.0STA32**
Teaching Scheme	**Examination Scheme**	**Credit 03**
Theory: 2 hrs/ week Practical: 2 hrs/week	End Semester Examination: 60 Marks Internal Assessment: 20 + 20 Marks	Theory: 3
	Total: 100 Marks	Total: 3

Course Pre-requisites: Student must have knowledge of

2. Statistical inference
3. Nonparametric inference
4. Regression analysis

Course Objective:

The main objective of this paper is to make students understand computationally intensive methods for doing statistical inference.

Learning Outcome:

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

1. Understand the necessity of resampling methods.
2. Recall missing data imputation techniques to impute missing values.
3. Develop programing codes for computationally intensive methods.
4. Evaluate different statistical algorithms using cross validation.
5. Apply various Bayesian techniques to analyze real life problems.

Course Content :

Unit No.	**Unit Contents**	**No. of Hrs**
1	Resampling Techniques: Resampling paradigms, bias-variance trade-off. Bootstrap methods, estimation of sampling distribution, confidence interval, variance stabilizing transformation. Jackknife and cross-validation. Jackknife in sample surveys. Jackknife in regression under heteroscedasticity. Permutation tests.	11
2	Missing Values and Imputations Techniques: Missing values and types of missingness, imputations methods for missing values, single and multiple imputations. EM Algorithm and Applications: EM algorithm for incomplete data, EM algorithm for mixture models, EM algorithm for missing values, stochastic EM algorithm.	11
3	Smoothing techniques: Kernel estimators, nearest neighbor estimators, orthogonal and local polynomial estimators, wavelet estimators. Splines. Choice of bandwidth and other smoothing parameters.	11
4	Bayesian computing, Markov Chain Monte Carlo. Simulation using MCMC, MCMC methods for missing values.	12

Reference/Text Books:

1. Buuren, Stef van (2012). Flexible Imputation of Missing Data. Chapman and Hall.
2. Chihara, L. and Hesterberg, T. (2011) Mathematical Statistics with Resampling and R. Wiley.
3. Davison, A.C. and Hinkley, D.V. (1997) Bootstrap methods and their Applications. Chapman and Hall.
4. Efron, B. and Tibshirani. R.J. (1994); An Introduction to the Bootstrap. Chapman
5. and Hall.
6. Christensen R, Johnson, W., Branscum A. and Fishman, G.S. (1996) Monte Carlo:

Concepts, Algorithms, and Applications. Springer.
7. Gilks, W. R., Richardson, S., and Spiegelhalter, D. (eds.) (1995) Markov Chain Monte Carlo in Practice. Chapman and Hall.
8. Good, P. I. (2005) Resampling Methods: A Practical Guide to Data Analysis. Birkhauser Bosel.
9. Hanson T. E. (2011). Bayesian Ideas and Data Analysis: An Introduction for Scientists and Statisticians, Chapman Hall.
10. Jim, A. (2009). Bayesian Computation with R, 2nd Edn, Springer.
11. Kennedy W. J. Gentle J. E. (1980) Statistical computing. Marcel Dekker.
12. McLachlan, G.J. and Krishnan, T. (2008) The EM Algorithms and Extensions. Wiley.
13. Rubinstein, R.Y. (1981); Simulation and the Monte Carlo Method. Wiley.
14. Shao J. and Tu, D. (1995); The Jackknife and the Bootstrap. Springer Verlag.

COs – POs Mapping matrix for STA482/6.0STA32: Computer Intensive Statistical Methods (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	2	1	2
CO-2	3	2	3	1	3
CO-3	2	3	2	1	3
CO-4	3	3	3	1	3
CO-5	3	3	3	1	3
Total	**14**	**14**	**13**	**5**	**14**
Average	**2.8**	**2.8**	**2.6**	**1**	**2.8**

Course Name: Machine Learning (Elective)		**Course Code: STA 484/6.0STA33**
Teaching Scheme	**Examination Scheme**	**Credit: 03**
Theory: 2 hrs/ week Practicals : 2 hrs/week	End Semester Examination: 60 Marks Internal Assessment: 20 + 20 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

(i) Linear algebra
(ii) Multivariate statistics
(iii) Regression

Course Objective:

1. The objective is to familiarize the audience with some basic learning algorithms and techniques and their applications, as well as general questions related to analyzing and handling large data sets.
2. Several libraries and data sets are publicly available, that will be used to illustrate the application of machine learning algorithms.
3. The emphasis will be on machine learning algorithms and applications, with some broad explanation of the underlying principles.
4. To develop the basic skills necessary to pursue research in machine learning.
5. To develop the design and programming skills that will help you to build intelligent, adaptive artifacts.

Course Outcomes:

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

1. Understand different types of learning methods.
2. Recognize different prediction models.
3. Apply different clustering algorithms to real life data.
4. Compare different machine learning algorithms.
5. Perform classification of massive data using appropriate machine learning algorithms.

Course Content:

Unit No.	**Unit Contents**	**No. of Hrs**
1	Introduction to machine learning, learning methods, supervised learning, unsupervised learning, data preprocessing, problem of classification, logistic regression as a classifier, k-nearest neighbor classifier, naïve Bayes classifier, artificial neural networks, classification trees, support vector machines, linear discriminant analysis, multiclass classification. Imbalance data and related problems. Accuracy measures, model validation, k-fold cross validation.	20
2	Clustering: K-Means, hierarchical clustering-agglomerative, divisive, distance measures, density-based clustering – DBscan, spectral clustering. Selection of appropriate number of clusters, CLARA, DENCLUE..	10
3	Ensemble Methods: Boosting-adaboost, gradient boosting, bagging - simple methods, random forest, hyper parameter tunning.	10
4	Dimensionality Reduction: Principal component analysis, t-SNE, Association rule mining	5

Reference/Text Books:

1. Pattern Recognition and Machine Learning. Christopher Bishop.
2. Machine Learning. Tom Mitchell.
3. Pattern Classification. R.O. Duda, P.E. Hart and D.G. Stork.

4. Data Mining: Tools and Techniques. Jiawei Han and Michelline Kamber.
5. Elements of Statistical Learning. Hastie, Tibshirani and Friedman. Springer.

COs – POs Mapping matrix for STA 484/6.0STA33: Machine Learning
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	3	1	1	3
CO-3	2	3	2	1	3
CO-4	3	3	2	1	3
CO-5	2	3	3	1	3
Total	**13**	**14**	**9**	**5**	**14**
Average	**2.6**	**2.8**	**1.8**	**1**	**2.8**

LIST OF ELECTIVES FOR SEMESTER IX

Couse Name: Econometrics (Elective)		**Course Code: STA581/6.5STA31**
Teaching Scheme	**Examination Scheme**	**Credit Allotted : 3**
Theory: 3 hrs/ week	CIA: 20+20 Marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Correlation regression
2. Multivariate data analysis

Course Objective:

The main objective is to introduce branch which is an integration of mathematics, statistics, and economics used to deal with econometric models.

Course Outcomes:

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

1. Understand the properties and problems of econometric models.
2. Recall various estimation and testing of hypothesis procedures in econometric models.
3. Understand the concept of panel data models.
4. Identify the fixed and random effect models.
5. Apply Simultaneous Equation Models to analyse the economic data.

Course Content :

Unit No.	**Unit Contents**	**No. of Hrs**
1	Introduction of Econometrics, Multiple Linear Regression Model, Model with non-spherical disturbances, Test of Auto-correlation, restricted regression estimator, Errors in variables, Dummy variables, Logit and Probit Models. Problem of heteroscedasticity, general Gauss-Markov theorem, generalized weighted least square estimators,	**15**
2	Seemingly unrelated regression equation (SURE) model and its Estimation, Simultaneous equations model, concept of structural and reduced forms problem of identification, rank and order condition of identifiability.	**15**
3	Methods of estimation of simultaneous equation model: indirect least squares, two stage least squares and limited information maximum likelihood estimation, idea of three stage least squares and full information maximum likelihood estimation, and prediction	**10**
4	Panel data models: Estimation in fixed and random effect models, Panel data unit root test	**05**

Reference/Text Books:

1. Apte, P.G.: Text books of Econometrics, Tata McGraw Hill.
2. Gujarathi, D.: Basic Econometrics; McGraw Hill.
3. Johnston, J.: Econometrics Methods. Third edition, McGraw Hill.
4. Srivastava, V.K. and Giles D. A. E.: Seemingly unrelated regression equations models, Marcel Dekker.
5. Ullah, A. and Vinod, H.D.: Recent advances in Regression Methods, Marcel Dekker.

COs – POs Mapping matrix for STA581/6.5STA31: Econometrics
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	2	2	2
CO-2	2	3	3	1	2
CO-3	3	2	2	1	2
CO-4	2	3	2	1	2
CO-5	2	3	3	1	3
Total	**12**	**13**	**12**	**6**	**11**
Average	**2.4**	**2.6**	**2.4**	**1.2**	**2.2**

Course Name : Discrete Data Analysis (Elective)		**Course Code: STA582/6.5STA32**
Teaching Scheme	**Examination Scheme**	**Credit 03**
Theory: 3 hrs/ week	CIA: 20+20 Marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

3. ANOVA
4. Regression Analysis

Course Objective:

The main objective of this course is to introduce discrete data analysis.

Course Outcomes:

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

1. Understand categorical data and its related inferences.
2. Understand fitting of generalized linear models and its analysis using goodness of fit criterion.
3. Understand the utilization of suitable link function which will help them to apply generalized linear models.
4. Analyze categorical data using logistic regression framework.
5. Apply Poisson and Negative Binomial regression to real life data sets.

Course Content :

Unit No.	**Unit Contents**	**No. of Hrs**
1	**Log linear model**: Log linear model for two and three dimensional contingency tables: Interpretation of parameters, comparison with ANOVA and regression. ML estimation of parameters, likelihood ratio tests for various hypotheses including independence marginal and conditional independence, partial association, models with quantitative levels.	**15**
2	**Generalized linear models**: concept of generalized linear model, Link function, ML estimation, Quasi-likelihood estimation, large sample tests about parameters, goodness of fit, analysis of deviance. Residual analysis, types of residuals: raw, Pearson, deviance, Anscombe, quantile; residual plots. Variable selection: AIC and BIC.	**15**
3	**Regression models for count data,** Poisson regression, and problem of over dispersion, Quasi-likelihood, NB1, NB2 models. Introduction to generalized mixed linear models.	**15**

Reference/Text Books:

1. Yuvonne M. Bishop, Stephen E. Fienberg, Paul W. Holland (1975): Discrete Multivariate Analysis: Theory and Practice
2. Hosmer D.W. and Lemeshow S. (2000): Applied Logistic regression, 2nd ED. Wiley New York.
3. Agesti A. (1990): Categorical Data Analysis. Wiley, New York.
4. R.Christensen (1997) Log-Linear Models and Logistic Regression, Springer. New York.
5. Hilbe, J. (2011): Negative Binomial regression, Cambridge University, Press, 2nd Edition.
6. McCulloch, C. E., & Searle, S. R. (2004). Generalized, linear, and mixed models. John Wiley & Sons.

COs – POs Mapping matrix STA582/6.5STA32: Discrete Data Analysis
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	2	1	2
CO-2	2	3	3	1	3
CO-3	2	3	2	1	2
CO-4	2	3	3	1	3
CO-5	2	3	3	1	3
Total	**11**	**14**	**13**	**5**	**13**
Average	**2.2**	**2.8**	**2.6**	**1**	**2.6**

Course Name : Nonparametric Statistics		Course Code : STA583/6.5STA33
Teaching Scheme	**Examination Scheme**	**Credit 03**
Theory: 3 hours/ week	CIA: 20+20 Marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

5. Parametric inference
6. Regression analysis
7. Analysis of variance

Course Objective:

1. To broaden mind in terms of thinking about data and inference in a nonparametric way.
2. To introduce useful nonparametric methods that you can apply while analyzing data
3. To familiarize with important topics in nonparametric statistics that you may wish to research.

Course Outcomes: After completion of this course student will able to

1. Understand basic concepts of nonparametric statistics.
2. Recall applications of nonparametric methods for analyzing data from variety areas.
3. Perform and interpret the nonparametric tests for different testing of hypothesis problems.
4. Identify multiple applications where nonparametric approaches are appropriate.
5. Compare the nonparametric methods with different methods.

Course Content:

Unit No.	Unit Content	No. of Hours
1.	Introduction to nonparametric statistics, advantages and disadvantages of nonparametric methods, kernel, U-statistic, one sample testing of hypothesis problem, sign test, signed rank test, two sample testing of hypothesis problem, two-sample U-statistics, Wilcoxon signed rank test, Mann-Whitney test, Wilcoxon signed rank test for paired sample problem.	15
2.	One-way Layout and two-way layout, Kruskal-Wallis test for one-way analysis of variance, multiple comparison procedures, Friedman tests for two-way analysis of variance.	15
3.	Problem goodness of fit, Chi-square goodness of fit test, Kolmogorov-Smirnov one-sample and two sample tests,	07
4.	Problem of density estimation, kernel function, naïve estimator, kernel estimators, nearest neighbour estimators, nonparametric regression, kernel regression, locally weighted regression.	08

Reference Books:

1. Gibbons, J. D., & Chakraborty, S. (2014). *Nonparametric statistical inference*. CRC press.
2. Conover, W. J. (1999). *Practical nonparametric statistics* (Vol. 350). John wiley & sons.
3. Silverman, B. W. (2018). *Density estimation for statistics and data analysis*. Routledge.
4. Montgomery, D. C., Peck, E. A., & Vining, G. G. (2021). *Introduction to linear regression analysis*. John Wiley & Sons.

E-Resources:

http://www.ru.ac.bd/stat/wp-content/uploads/sites/25/2019/03/501_13_Gibbons_Nonparametric_statistical_inference.pdf
https://nptel.ac.in/courses/111102143

COs – POs Mapping matrix STA583/6.5STA33: Nonparametric Statistics
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	2	2	2	1	2
CO-3	2	3	3	1	3
CO-4	2	2	2	1	2
CO-5	2	2	2	1	2
Total	**11**	**11**	**10**	**5**	**11**
Average	**2.2**	**2.2**	**2**	**1**	**2.2**

Course Name: Tools for Data Science (Elective)		**Course Code: STA584/6.5STA34**
Teaching Scheme Theory: 2 hrs/ week Practical: 2 hrs/week	**Examination Scheme** **CIA:** 20+20 Marks **ESE:** 60 Marks Total=100 Marks	**Credit : 3**

Course Pre-requisites: Student must have knowledge of

1. Machine learning, Statistics

Course Objective:

2. To understand and analyze the image and text data.

Course Outcomes: After completion of this course student will able to

6. Visualize data using advance visualization tools.
7. Analyze the image data.
8. Create language models for analyzing text data.
9. Apply machine learning models for image and text data.
10. Build interactive dashboards and visual analytics using advanced visualization tools and Tableau for data-driven insights.

Course Content:

Unit No.	**Unit Contents**	**No. of hrs**
1.	Data Visualization Techniques: ggplot2, Bar plots, Pei chart, Histogram, Boxplot, Boxplot for heavy tailed data, Violin plot, QQ-plot, PP-plot, Gini coefficient, Scatter plot, Bubble plot, Mosaic plots, Bag plot, Heatmap, corrgrams, Generalized pairs plots, Added variable plots, Contour plot, 2D density contour plot. Tablue: Basic reports, learn tablue charts, filters, dashborads.	15
2.	Image processing: Getting Started with images, Basic Operations on Images, Arithmetic Operations on Images, Image Preprocessing: changing colorspaces, geometric transformations, thresholding, smoothing, morphological transformations, gradients, Canny Edge detection, image pyramids, image segmentation with Watershed algorithm, Feature Detection and Description. Image Detection and recognition examples.	15
3.	Text Mining: Introduction to Natural Language Processing (NLP), Natural Language Toolkit (NLTK) in Python. Data Preparation: punctuation removal, stop-words removal, numeric value removal, frequent words removal, rare words removal, spelling correction, tokenization, stemming, lemmatization. Feature Engineering: count vectors as features, Term Frequency-Inverse Document Frequency (TF-IDF), TF-IDF vectors as features, word level TF-IDF, N-Gram level TF-IDF, Character level TF-IDF, world cloud, Inverse Document Frequency, word embedding as features, Text/NLP based features, Topic Models as features, word2vec, sentiment analysis.	15

Reference/Text Books:

1. Healy, K. (2018). Data visualization: a practical introduction. Princeton University Press.
2. Goodfellow, I., Bengio, Y., Courville, A., & Bengio, Y. (2016). Deep learning (Vol. 1). Cambridge: MIT press.
3. Shanmugamani R. (2018). Deep Learning for Computer Vision: Expert techniques to train advanced neural networks using TensorFlow and Keras. "Packt Publishing Ltd"
4. Bird, S., Klein, E., &Loper, E. (2009). Natural language processing with Python: analyzing text with the natural language toolkit. " O'Reilly Media, Inc.".
5. Hardeniya, N., Perkins, J., Chopra, D., Joshi, N., & Mathur, I. (2016). Natural Language Processing: Python and NLTK. Packt Publishing Ltd.
6. Mueller, J. P., &Massaron, L. (2015). Python for data science for dummies. John Wiley & Sons.

COs – POs Mapping matrix STA584/6.5STA34: Tools for Data Science
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	2	3	1	3
CO-2	1	3	3	1	3
CO-3	1	3	3	1	3
CO-4	1	3	3	1	3
CO-5	1	2	2	1	3
Total	**6**	**13**	**14**	**5**	**15**
Average	**1.2**	**2.6**	**2.8**	**1**	**3**

Course Name : Bayesian Inference (Elective)		Course Code: STA585/6.5STA35
Teaching Scheme	**Examination Scheme**	**Credit Allotted:03**
Theory: 3 hrs/ week	**CIA:** 20+20 Marks **ESE:** 60 Marks Total=100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Probability distributions
2. Statistical inference

Course Objective:

To know Bayesian approach to solve statistical decision problems and use Bayesian techniques for computation.

Course Outcomes:

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

1. Distinguish between frequentist and Bayesian approach.
2. Employ prior information for analyse of real life data.
3. Choose appropriate prior distributions.
4. Compute Bayes estimates for the population parameters.
5. Apply Bayesian theory in testing of hypothesis problems.

Course Content:

Unit No.	Unit Contents	No. of hrs
1	Frequentist vs. epistemic concepts of probability, Bayes's rule, prior and posterior distributions, likelihood, discrete probability examples, simple continuous distributions examples, popular R packages for Bayesian analysis. Bayesian linear regression, choice of priors, interpretation of model parameters, Bayesian inference, credibility intervals, Bayesian generalized regression modeling, examples in MCMC pack and rstanarm.	20
2	MCMC Estimation: MCMC estimation, Gibbs sampling, Hamiltonian Monte-Carlo, main convergence diagnostics, INLA, variational inference.	15
3	Bayes factors, Bayesian Information Criterion (BIC) and Deviance Information Criterion (DIC), WAIC, leave-one-out cross-validation.	10

Reference/Text Books:

1. Berger, J. O. : Statistical Decision Theory and Bayesian Analysis, Springer Verlag.
2. Robert, C.P. and Casella, G. : Monte Carlo Statistical Methods, Springer Verlag.
3. Leonard, T. and Hsu, J.S.J. : Bayesian Methods, Cambridge University Press.
4. Bernando, J.M. and Smith, A.F.M. : Bayesian Theory, John Wiley and Sons.
5. Robert, C.P. : The Bayesian Choice: A Decision Theoretic Motivation, Springer.
6. Gemerman, D. : Markov Chain Monte Carlo: Stochastic Simulation for Bayesian Inference, Chapman Hall.
7. Box, G.P. and Tiao, G. C.: Bayesian Inference in Statistical Analysis, Addison-Wesley.

COs – POs Mapping matrix STA585/6.5STA35: Bayesian Inference
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	2	2
CO-2	2	3	3	1	3
CO-3	2	3	2	1	2
CO-4	2	3	3	1	3
CO-5	2	3	3	1	3
Total	**11**	**14**	**12**	**6**	**13**
Average	**2.2**	**2.8**	**2.4**	**1.2**	**2.6**

Course Name: Optimization Techniques (Elective)	Course Code : STA 586/6.5STA36

Teaching Scheme	Examination Scheme	Credit: 3
Theory: 3 hrs/ week	CIA: 20+20 Marks ESE: 60 Marks Total: 100 Marks	

Pre-requisite:
Operation research, Stochastic processes.

Course Objective:

1. to formulation of the dynamic and integer programming and its solutions
2. to design decision making problem and to find optimal solution
3. to understand the mathematical modeling of a queuing problem and its solution
4. to formulate the inventory and replacement problems and to find its solution

Course Outcomes: After completion of this course student will able to

1. design the dynamic and integer programming problems and its solutions
2. find an optimal strategies and solution of the given decision making problem
3. modeling and find a solution of a given queuing problem
4. understand an inventory and replacement problems
5. use appropriate optimization software/tools to solve real-life operations research problems.

Course Content:

Unit No.	Unit Content	No. of Hrs
5.	Dynamic programming - Bellman's principle of optimality, general formulation. Integer Programming-Modelling using pure and mixed integer programming, Gomory's Cutting Plane Algorithm. Branch and Bound technique. Stochastic Programming.	12
6.	Decision-making in the face of competition, two-person games, pure and mixed strategies, existence of solution and uniqueness of value in zero-sum games, finding solutions in 2x2, 2xm and mxn games. Solution 3x3 game by using simplex procedure.	12
7.	Queuing models – specification and effectiveness measures. Steady-state solutions of M/M/1 and M/M/c models with associated distributions of queue-length and waiting time. M/G/1 queue and Pollazcek-Khinchine result.	09
8.	Inventory Models– Analytical structure, Deterministic and Probabilistic Models, ABC Classification, EOQ analysis and extensions allowing quantity discounts and shortages. Replacement problems: Block and age replacement policies. Replacement of items that fail gradually and stochastically.	12

Reference Books:

1. F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009.
2. Hadley, G: (2002) : Linear Programming, Narosa Publications
3. Hamdy A. Taha, Operation research-An Introduction, Prentice Hall, 8th Ed., 2007
4. J. K. Sharma, Operations Research Theory & Applications, Macmillan India Limited.
5. Kanti Swarup, Gupta, P.K. and Manmohan (2007): Operations Research, 13th Edition, Sultan Chand and Sons
6. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004
7. Ravindran, A, Phillips, D.T., Solberg, J.J.(2005): Operations Research- Principles and Practice, John Wiley & Sons
8. Taha, H. A. (2007): Operations Research: An Introduction, 8th Edition, Prentice Hall of India
9. V. K. Kapoor, Operations Research, Sultan Chand & Sons

COs – POs Mapping matrix STA586/6.5STA36: Optimization Techniques
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	3	3	1	3
CO-2	2	3	3	1	3
CO-3	2	3	3	1	3
CO-4	2	2	2	1	3
CO-5	1	3	3	1	3
Total	**9**	**14**	**14**	**5**	**15**
Average	**1.8**	**2.8**	**2.8**	**1**	**3**

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