Appendix - VI (F)

Five-Year Integrated M.Sc. (STATISTICS) ACADEMIC PROGRAM

Scheme of Examinations and Syllabus for
the Five-Year Integrated M.Sc. Degree
Programmes in **Statistics**

(2024 Admission Onwards)

Department Specific/Elective Core Papers for

Major, Minor and Multi-Disciplinary Courses

Department of Statistics

Cochin University of Science and Technology

Vision

To become a global center of excellence in the conservation, creation, advancement, and dissemination of knowledge in the field of statistics and allied subjects.

Mission

- To impart quality education in statistics to achieve excellence in teaching, research and consultancy.
- To generate cutting-edge research and innovations in statistics and allied areas to enable empowerment for economic, technological and social development.
- To strengthen international collaborations to spread the wings CUSAT globally for teaching and research in statistics and allied areas.

Program Outcomes - Integrated M.Sc.

- PO1: Demonstrate a comprehensive understanding of fundamental principles and concepts in basic sciences.
- PO2: Analyze, evaluate, and synthesize complex scientific information and data using appropriate methods and techniques.
- PO3: Apply scientific reasoning and critical thinking adeptly to recognize, assess, and resolve problems encountered in various scientific contexts.
- PO4: Utilize computational power, programming languages, and modern technologies proficiently to address scientific challenges, effectively integrating technological solutions into problem-solving processes.
- PO5: Communicate scientific information effectively and demonstrate proficiency in the use of modern scientific tools and technologies for experimentation, data collection, analysis, and interpretation.
- PO6: Adhere to ethical principles and practices in the conduct of scientific research and professional activities, and work collaboratively with others.
- PO7: Engage in lifelong learning and professional development to enhance the knowledge and skills in basic sciences.

Program Specific Outcomes - Integrated M.Sc. Major in Statistics

- PSO1: Understand the role of probability and statistics in solving real life problems.
- PSO2: Apply the knowledge on modern statistical techniques relevant for today's scientific community.
- PSO3: Illustrate the need for systematic analysis of data in any scientific experiment.

- PSO4: Practise statistical knowledge for the consultancy on experimental design and field survey.
- PSO5: Develop professionally inclined statistics teachers/statistician/data scientist who have sound knowledge of the subject matter and specialized in knowledge discovery through statistical methods.
- PSO6: Apply basic theoretical and applied principles of statistics with adequate preparation to pursue a Doctoral (Ph.D.) degree or enter job force as an applied statistician.
- PSO7: Translate key statistical concepts to non-statisticians.
- PSO8: Develop proficiency in using statistical software/utility for data analysis.

Integrated M.Sc. Statistics Scheme (2024 Admissions Onwards)

Semester	Number of courses offered by the department						Total
	Major- 4 credits	Minor - 4 credits	MDC - 3 credits	AEC- 3 credits	SEC - 3 credits	VAC - 3 credits	
I	1	2	1	2*			21
II	1	2	1	2*			21
III	1	2	1			2*	21
IV	4				1	1*	22
V	5				1		23
VI	5**				1		23
	Internship* **						2
Total Credits /Courses	68(17); DSC 60(15); DSE 08(04)	24(6)	9(3)	12(4)	9(3)	9(3)	133
* Courses offered by the Center for Integrated Studies CUSAT ** Instead of one course with 4 credits a student may take one or two online courses to acquire 4 credits *** Not counted as a course and should be completed before the end of Vth semester **Exit with B.Sc. in Statistics (Total credits = 133)**							
VII	5†						22
VIII	2†† OR 4†††						22
† and seminar or open ended labs or online course of 2 credits †† and seminar or open ended labs or online course of 2 credits + Project with 12 credits ††† and seminar or open ended labs or online course of 2 credits + Mini Project with 4 credits							
Total Credits /Courses	Hon (Research): 112 (24+ Project (12) + Practicals (4)) Hon: 112 (26 + Mini Project (4) + Practicals (4))	24 (6)	9 (3)	12 (4)	9(3)	9 (3)	177
Exit with B.Sc.(Honours with Research) in Statistics (Total credits = 177) **Exit with B.Sc. (Honours) in Statistics (Total credits = 177)**							
IX	5 + Online (2-4 credit⊗)						20-24
X	2⊗⊗ + Online (2-4 credit⊗)						20-24
Total Credits/ Courses	156 (35 + Mini project + Major project)	24(6)	9(3)	12(4)	9(3)	9(3)	221
⊗ Online course of 2-4 credits can be taken in IX or X Semesters, so total credit for online course is 4 ⊗⊗ and Major Project with 12 credits							
Exit with M. Sc. in Statistics (Total credits = 221)							

Academic pathways offered by the Department of Statistics

- **Statistics Major:**
  - 3-year UG Program: To earn a Statistics Major in a 3-year UG Program, a student must complete a minimum of 68 credits in Statistics, out of which 60 credits shall be from DSC courses and 8 credits from DSE courses.
  - 4-year UG Program (Honours): To earn a Statistics Major in a 4-year UG Program (Honours), a student must complete a minimum of 112 credits in Statistics, out of which 96 credits shall be from DSC courses and 16 credits from DSE courses.
  - 4-year UG Program (Honours with Research): To earn a Statistics Major in a 4-year UG Program (Honours with Research), a student must complete a minimum of 112 credits in Statistics, out of which 92 credits shall be from DSC courses and 8 credits from DSE courses and 12 credits from a research project.
  - 5-year PG Program: To earn a Statistics Major in a 5-year PG Program , a student must complete a minimum of 156 credits in Statistics, out of which 120 credits shall be from DSC courses and 24 credits from DSE courses and 12 credits from a research project.
- **Statistics Minor:**
  - 3-year UG Program: To earn a Minor in Statistics in a 3-year UG Program, a student must complete a minimum of 27credits in Statistics, out of which 24 credits shall be from DSC courses and 03 credits from an SEC elective.
  - 4-year UG Program: To earn a Minor in Statistics in a 4-year UG Program, a student must complete a minimum of 35 credits in Statistics, out of which 24 credits shall be from DSC courses and 3 credits from an SEC elective 8 credits from DSE courses.
- **Discipline mention in Statistics:**
  - To earn a Discipline mention in Statistics in a UG Program (3 or 4 years), a student must complete a minimum of 12 credits in Statistics from DSC courses.

Scheme

Semester I

Semester Credit: 21 (AEC: 6, Major: 4, Minor: 8, MDC: 3); Cumulative Credit: 21								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0101	Introductory Statistics	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0102	Applied Statistics	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0103	Basic Statistics	MDC	None	2-0-2	3	50	50	100

- H/W for L-T-P stands for Hours/Week for Lecture- Tutorial-Practical
- AEC – Ability Enhancement Course;
  MDC – Multidisciplinary Course;
  VAC – Value Added Course;
  SEC – Skill Enhancement Course;
  DSC - Department Specific Core:
  DSE - Department Specific Elective. Multi-Disci - Statistics Disciplinary
- Students can choose either
  - Single major path way - Statistics single Major OR
  - Major with minor pathway - Statistics Major with Mathematics/Physics/Computer Science (Artificial Intelligence) / Biological Sciences as Minor OR
  - Major with Multi disciplinary path way- Statistics Major with Mathematics and/or Physics and/or Computer Science (Artificial Intelligence) and/or Biological Sciences as Multi Disciplinary choices.

Semester II

Semester Credit: 21 (AEC: 6, Major: 4, Minor: 8, MDC: 3); Cumulative Credit: 42								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0201	Introduction to Probability Theory	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0202	Probability Distributions	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0203	Probability Theory and Random Variables	MDC	None	2-0-2	3	50	50	100

Semester III

Semester Credit: 21 (Major: 4, Minor: 8, MDC: 3, VAC: 6); Cumulative Credit: 63								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0301	Statistical Methods	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0302	Statistical Inference	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0303	An Introduction to Statistical Methods	MDC	None	2-0-2	3	50	50	100

Semester IV

Semester Credit: 22 (Major: 16, SEC: 3, VAC: 3); Cumulative Credit: 85								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0401	Discrete Distributions	STAT Major - DSC	24-810-0201	3-0-2	4	50	50	100
24-810-0402	Continuous Distributions	STAT Major - DSC	24-810-0201	3-0-2	4	50	50	100
24-810-0403	Bivariate Data Analysis	STAT Major - DSC	24-810-0101	3-0-2	4	50	50	100
24-810-0404	Sampling Theory and Methods - I	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0405	Statistical Data Analysis Using R - I	SEC	None	1-0-4	3	50	50	100

Semester V

Semester Credit: 23 (Major: 20, SEC: 3); Cumulative Credit: 108								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0501	Statistical Inference - I	STAT Major - DSC	24-810-0201/0202	3-0-2	4	50	50	100
24-810-0502	Statistical Quality Control	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0503	Operations Research - I	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0504	Time Based Data and Index Numbers	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-05xx	Elective - I	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0508	Statistical Data Analysis Using Python	SEC	None	1-0-4	3	50	50	100
Elective - I (Choose any one course)								
24-810-0505	Machine Learning	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0506	Actuarial Statistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0507	Financial Statistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100

Semester VI

Semester Credit: 23 (Major: 20, SEC: 3); Cumulative Credit: 131								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0601	Statistical Inference - II	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0602	Design and Analysis of Experiments - I	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0603	Multivariate Methods	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0604	Survival Analysis	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-06xx	Elective - II	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0608	Statistical Data Analysis Using R - II	SEC	24-810-0508	1-0-4	3	50	50	100
Elective - II (Choose any one course)								
24-810-0605	Introduction to Data Mining	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0606	Econometrics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	0-2-0	4	50	50	100
24-810-0607	MOOC	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	0-2-0	4	-	100	100
Internship (Not counted as a course): 2 credits								

- Students can exit with B.Sc. Statistics (Total Credits=133)

Semester VII

Semester Credit: 22 (Major: 20, Seminar/Open ended labs/Online course: 2); Cumulative Credit: 155								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0701	Mathematical Methods for Statistics	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0702	Probability Theory	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0703	Family of Distributions	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0704	Sampling Theory and Methods - II	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-07xx	Elective - III	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0708	Practical-I and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
Elective - III (Choose any one course)								
24-810-0705	Categorical Data Analysis	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0707	Population Dynamics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0707	Biostatistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100

- [a] End semester evaluation based on viva voce.

Semester VIII

B.Sc (Honours) in Statistics								
Semester Credit: 22 (Major: 20; seminar/open ended labs/online course: 2); Cumulative Credit: 177								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0801	Theory of Estimation	STAT Major - DSC	24-810-0703	2-1-2	4	50	50	100
24-810-0802	Stochastic Processes	STAT Major - DSC	24-810-0702	2-1-2	4	50	50	100
24-810-0803	Advanced Techniques for Data Analysis	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0804	Mini Project	STAT Major - DSC	None	0-4-0	4	50	50[b]	100
24-810-08xx	Elective - IV	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0808	Practical-II and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
Elective - IV (Choose any one course)								
24-810-0805	Reliability Modelling and Analysis	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0806	Introduction to Information Theory	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0807	Statistical Analysis of Clinical Trials	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
Exit with B.Sc. (Honours) in Statistics (Total credits = 177)								
B.Sc (Honours with Research) in Statistics								
24-810-0801	Theory of Estimation	STAT Major - DSC	24-810-0703	2-1-2	4	50	50	100
24-810-0802	Stochastic Processes	STAT Major - DSC	24-810-0702	2-1-2	4	50	50	100
24-810-0808	Practical-II and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
24-810-0809	Project	STAT Major - DSC	None	0-12-0	12	50	50[b]	100
Exit with B.Sc. (Honours with Research) in Statistics (Total credits = 177).								

- [a] End semester evaluation based on viva voce;
- [b] End semester evaluation based on the presentation and project report.

Semester IX

Semester Credit: 22-24 (Major: 20, Online Course: 2-4); Cumulative Credit: 199-201								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0901	Testing of Hypothesis	STAT Major - DSC	24-810-0801	2-1-2	4	50	50	100
24-810-0902	Multivariate Analysis	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	24-810-0302 (To choose as DSE)	2-1-2	4	50	50	100
24-810-0903	Applied Regression Analysis	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	24-810-0302 (To choose as DSE)	2-1-2	4	50	50	100
24-810-0904	Design and Analysis of Experiments-II	STAT Major - DSC	24-810-0801	2-1-2	4	50	50	100
24-810-09xx	Elective - V	STAT Major - DSE	24-810-0503	2-1-2	4	50	50	100
24-810-0908	MOOC (2-4 credits)[c]	STAT Major - DSE	None	0-2-0	2-4	-	100	100
Elective - V (Choose any one course)								
24-810-0905	Operations Research - II	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0906	Reliability Engineering	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0907	Applications of Integral Transforms	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100

- [c] A MOOC of 2-4 credits should be opted by the student with the approval of the Department Council.

Semester X

Semester Credit: 22-24 (Major: 20, Online Course: 2-4); Cumulative Credit: 221								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-1001	Time Series Analysis	STAT Major - DSC	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1002	Project Work	STAT Major - DSC	None	0-12-0	12	50	50[b]	100
24-810-10xx	Elective - VI	STAT Major - DSE	24-810-0503	2-1-2	4	50	50	100
24-810-1007	MOOC (2-4 credits)[c]	STAT Major - DSE	None	0-2-0	2-4	-	100	100
Elective - VI (Choose any one course)								
24-810-1003	Lifetime Data Analysis	STAT Major - DSE	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1004	Spatial Statistics	STAT Major - DSE	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1005	Advanced Bayesian Computing	STAT Major - DSE	None	2-1-2	4	50	50	100
24-810-1006	Statistics for Clinical Research	STAT Major - DSE	None	2-1-2	4	50	50	100

- [b] End semester evaluation will be done based on the presentation and project report.
- [c] A MOOC of 2-4 credits should be opted by the student with the approval of the Department Council.
- Instead of taking two online courses worth 2 credits each, a student can opt for one online course worth 4 credits in the ninth semester. In such cases, the credits earned in the ninth semester will be 24, and in the tenth semester, they will be 20.
- Exit with M.Sc. in Statistics (Total credits = 221)

Semester I

Semester Credit: 21 (AEC: 6, Major: 4, Minor: 8, MDC: 3); Cumulative Credit: 21								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0101	Introductory Statistics	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0102	Applied Statistics	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0103	Basic Statistics	MDC	None	2-0-2	3	50	50	100

24-810-0101 Introductory Statistics

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify different type of data and their preliminary analysis	Understand
2.	Interpret and analyse important measures of central tendency	Analyse
3.	Interpret and analyse various measures of dispersion and calculation of them	Analyse
4.	Illustrate various moments	Analyse
5.	Calculate skewness and kurtosis and their interpretations	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	3	2			3	
CO2	3	1	2				2	1
CO3	2	2		2			3	1
CO4	2	1					3	1
CO5	2	1					2	1

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction - scope and importance of statistics; Types of data - nominal, ordinal, interval, and ratio; Graphical representation of data- bar diagram, pie diagram, histogram, frequency polygon and ogives, Box-Whisker plot, stem and leaf diagram. (10 Hours)

Module 2:

Measures of central tendency- arithmetic mean, median, mode, geometric mean, harmonic mean and weighted averages; Examples and related problems for different types of data. (14 Hours)

Module 3:

Measures of dispersion - range, quartile deviation, mean deviation and standard deviation, combined mean and standard deviation, relative measures of dispersion, coefficient of variation; Partition values- quartiles, deciles, percentiles; Examples and related problems for different types of data; Lorenz curve and Gini index. (18 Hours)

Module 4:

Raw and central moments, interrelationship among first four moments; Skewness - Pearson's, Bowley's and moment measures, kurtosis; Examples and related problems for different types of data; Practical using MS excel- introduce various charts and diagrams, calculation of measures of central tendencies, dispersion, moments and measures of skewness and kurtosis. (18 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Ross, S. M. (2017). *Introductory Statistics*, 4^{th} Edition. Academic Press, India.

References:

1. Elhance, D. N., Elhance V. and Aggarwal B. M. (2018). *Fundamentals of Statistics*. Kitab Mahal, New Delhi.

2. Gupta, S. P. (2021). *Statistical Methods*, 46^{th} Edition. Sultan Chand and Sons, New Delhi.

3. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New Delhi.

24-810-0102 Applied Statistics

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Distinguish different types of data collection methods and their preliminary analysis	Understand
2.	Interpret and understand bivariate data and properties	Apply
3.	Analyse association measures for bivaraite data	Analyse
4.	Examine the relationship between two variables using the method of regression	Analyse
5.	Practice the calculation of correlation and regression methods	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2	1				2	
CO2	3	2	1				2	
CO3	3	1	2		1		3	
CO4	3	2			2		2	
CO5	2			2	2		2	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Primary and secondary data, population and sample, census and survey sampling, sampling and non - sampling errors, types of sampling - simple random sampling (with and without replacement), stratified sampling, systematic sampling, cluster sampling, non-probability sampling. (10 Hours)

Module 2:

Bivariate data, scatter diagram, Pearson's correlation coefficient, properties, Spearman's rank correlation coefficient, repeated ranks, ϕ coefficient, Cramers's V, Kendall's τ - related problems. (15 Hours)

Module 3:

Principle of least squares, linear regression, regression coefficients, properties, curve fitting - for straight line, quadratic curve, exponential curves - related problems. (20 Hours)

Module 4:

Practical using MS excel- calculation of correlation coefficient for different types of data; Curve fitting of straight line, quadratic curve, exponential and power curves; Calculation of regression coefficient and regression lines, interpreting the results. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Ross, S. M. (2017). *Introductory Statistics*, 4^{th} Edition. Academic Press, India.

References:

1. Elhance, D. N., Elhance V. and Aggarwal B. M. (2018). *Fundamentals of Statistics*. Kitab Mahal, New Delhi.

2. Gupta, S. P. (2021). *Statistical Methods*, 46^{th} Edition. Sultan Chand and Sons, New Delhi.

3. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New York.

24-810-0103 Basic Statistics

Credits (H/W for L-T-P): 3 (2-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify different type of data and their preliminary analysis	Understand
2.	Interpret and analyse important measures of central tendency	Analyse
3.	Interpret and analyse various measures of dispersion and calculation of them	Analyse
4.	Illustrate various moments	Analyse
5.	Calculate skewness and kurtosis and their interpretations	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	3	2			3	
CO2	3	1	2				2	1
CO3	2	2		2			3	1
CO4	2	1					3	1
CO5	2	1					2	1

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction - scope and importance of statistics; Types of data - nominal, ordinal, interval, and ratio; Graphical representation of data - bar diagram, pie diagram, histogram, frequency polygon and ogives. (10 Hours)

Module 2:

Averages - Arithmetic mean, median, mode, geometric mean, harmonic mean and weighted averages; Partition values; Examples and related problems for different types of data. (14 Hours)

Module 3:

Absolute measures of dispersion - range, quartile deviation, mean deviation and standard deviation, properties; Relative measures of dispersion; Examples and related problems for different types of data. (18 Hours)

Module 4:

Raw and central moments, interrelationship among first four moments, Skewness - Pearson's, Bowley's and moment measure, kurtosis; Examples and related problems for different types of data. (18 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Ross, S. M. (2017). *Introductory Statistics*, 4^{th} Edition. Academic Press, India.

References:

1. Elhance, D. N., Elhance V. and Aggarwal B. M. (2018). *Fundamentals of Statistics*. Kitab Mahal, New Delhi.

2. Gupta, S. P. (2021). *Statistical Methods*, 46^{th} Edition. Sultan Chand and Sons, New Delhi.

3. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New Delhi.

Semester II

Semester Credit: 21 (AEC: 6, Major: 4, Minor: 8, MDC: 3); Cumulative Credit: 42								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0201	Introduction to Probability Theory	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0202	Probability Distributions	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0203	Probability Theory and Random Variables	MDC	None	2-0-2	3	50	50	100

24-810-0201 Introduction to Probability Theory

Credits (H/W for L-T-P) : 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Discuss the basic principles of probability including theorems on probability and use these principles in problem solving situations	Understand
2.	Demonstrate basic probability relations including conditional probabilities and Bayes' Law	Apply
3.	Employ the definitions of univariate and bivariate random variables	Apply
4.	Calculate the density and distribution function of a random variable	Analyse
5.	Differentiate the marginal density and distribution function from the joint density function and distribution function	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2			3	3	1	
CO2	3	1		2	3	3	1	
CO3		3		1	3	3		
CO4	3	2		1	3	3		
CO5	3	2		1	3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Basic terminologies - introduction, random experiments, sample space, events and algebra of events, preliminaries of sets; Definitions of Probability - classical, statistical, and axiomatic; theorems on probability, addition theorem and extension, Boole's inequality. (10 Hours)

Module 2:

Conditional probability, multiplication theorem of probability, independence of events, pairwise independent events, extended axiom of addition and axiom of continuity, Bayes' theorem and problems on Bayes' theorem. (10 Hours)

Module 3:

One - dimensional random variables - introduction, definition and examples; Distribution function (DF) - definition, properties; Discrete random variable - probability mass function (pmf), discrete DF and problems; Continuous random variables - probability density function (pdf), continuous DF and problems; transformation of one dimensional random variable. (20 Hours)

Module 4:

Two - dimensional random variables - definition, joint, marginal and conditional probability distribution functions of discrete and continuous random variables; Distribution function - definition and properties, marginal DF, conditional DF; independence of random variables, generalization to n-dimensional random variable. (20 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Ross, S. M. (2022). *A First Course in Probability*, 10^{th} Edition. Pearson Education Limited, London.

References:

1. Blitzstein, J. K. and Hwang, J. (2019). *Introduction to Probability*, 2^{nd} Edition. CRC Press, New York.

2. Grinstead, C. M. and Snell, J. L. (1997). *Introduction to Probability*. American Mathematical Soc.

3. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

4. Spiegel, M. R., Schiller, J. J. and Srinivasan, R. A. (2013). *Schaum's Outline of Probability and Statistics*, 4^{th} Edition. McGraw-Hill Education, New York.

5. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New York.

24-810-0202 Probability Distributions

Credits (H/W for L-T-P) : 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Discuss various discrete distributions and properties	Understand
2.	Discuss various continuous distribution and properties	Understand
3.	Illustrate sampling distributions and interrelations	Analyse
4.	Demonstrate the fitting of distributions- binomial, Poisson, normal using Excel	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3				3	3		
CO2	3				3	3		
CO3			3		3	3	2	1
CO4	3		3		3	3	2	1

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Discrete distributions: Uniform, Bernoulli, binomial, Poisson, geometric - mean, variance, mgf, pgf and important properties; Negative binomial, hyper-geometric - definition and properties. (15 Hours)

Module 2:

Standard distributions - continuous type: uniform, normal, exponential, gamma, beta (type I and type II) - mean, variance, mgf, pgf and important properties; Lognormal, Pareto and Cauchy - definition and properties. (15 Hours)

Module 3:

Sampling distributions, distribution of sample mean and variance; Chi-square, Students-t, F-distributions - their interrelations and properties. (15 Hours)

Module 4:

Generating random variables; Fitting of distributions - binomial, Poisson, normal - theory and practical illustrations using MS Excel. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Ross, S. M. (2017). *Introductory Statistics*, 4^{th} Edition. Academic Press, India.

References:

1. Gupta, S. P. (2021). *Statistical Methods*, 46^{th} Edition. Sultan Chand and Sons, New Delhi.

2. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New York.

3. Elhance, D. N., Elhance V. and Aggarwal B. M. (2018). *Fundamentals of Statistics*. Kitab Mahal, New Delhi.

24-810-0203 Probability Theory and Random Variables

Credits (H/W for L-T-P) : 3 (2-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Discuss the basic principles of probability including theorems on probability and use these principles in problem solving situations	Understand
2.	Demonstrate basic probability relations including conditional probabilities and Bayes' Law	Apply
3.	Employ the definitions of univariate and bivariate random variables	Apply
4.	Calculate the density and distribution function of a random variable	Analyse
5.	Differentiate the marginal density and distribution function from the joint density function and distribution function	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2			3	3	1	
CO2	3	1		2	3	3	1	
CO3		3		1	3	3		
CO4	3	2		1	3	3		
CO5	3	2		1	3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction, preliminaries of sets, random experiments, sample space, events and algebra of events; Definitions of probability – classical, statistical, and axiomatic; Theorems on probability - addition theorem and extension. (10 Hours)

Module 2:

Conditional probability, multiplication theorem of probability, independence of events, pairwise and mutual independent, Bayes' theorem and problems on Bayes' theorem. (10 Hours)

Module 3:

Random variables - introduction, definition and examples; Distribution function (DF) - definition, properties; Discrete random variable - probability mass function (pmf), discrete DF and problems; Continuous random variables - probability density function (pdf), continuous DF and problems. (20 Hours)

Module 4:

Definition, joint probability mass function, marginal probability mass function, conditional probability function; Distribution function - definition and properties, marginal DF; joint and marginal density function, conditional DF and conditional pdf, independence of random variables.
(20 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.
2. Ross, S. M. (2022). *A First Course in Probability*, 10^{th} Edition. Pearson Education Limited, London.

References:

1. Spiegel, M. R., Schiller, J. J. and Srinivasan, R. A. (2013). *Schaum's Outline of Probability and Statistics*, 4^{th} Edition. McGraw-Hill Education, New York.
2. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New York.
3. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.
4. Blitzstein, J. K. and Hwang, J. (2019). *Introduction to Probability*, 2^{nd} Edition. CRC Press, New York.
5. Grinstead, C. M.and Snell, J. L. (1997). *Introduction to probability*. American Mathematical Society.

Semester III

Semester Credit: 21 (Major: 4, Minor: 8, MDC: 3, VAC: 6); Cumulative Credit: 63								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0301	Statistical Methods	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0302	Statistical Inference	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0303	An Introduction to Statistical Methods	MDC	None	2-0-2	3	50	50	100

24-810-0301 Statistical Methods

Credits (H/W for L-T-P) : 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the concept of mathematical expectation and its various properties	Understand
2.	Discuss various generating functions such as PGF, MGF, CGF, CF and its importance	Understand
3.	Understand different modes of convergence	Understand
4.	Evaluate various probability bounds using law of large numbers	Interpret

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2		3	3		
CO2	3			2	3	3		
CO3	3		2		3	3		
CO4	3			2	3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Mathematical expectation - mathematical expectation of a random variable and functions of a random variable, properties of expectation, inequalities of moments, conditional expectation. (15 Hours)

Module 2:

Generating functions - probability generating function, moment generating function, cumulant generating function and characteristic function; properties of generating function, uniqueness and inversion theorems (without proof) along with applications. (15 Hours)

Module 3:

Modes of convergence - convergence in probability, convergence in almost sure, convergence in distribution, convergence in r^{th} mean. (15 Hours)

Module 4:

Chebychev's inequality, weak law of large numbers, strong law of large numbers, central limit theorems (without proof). (15 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Hogg, R.V., Mckean, J. and Craig, A.T. (2018). *Introduction to Mathematical Statistics*, 8^{th} Edition. Pearson, USA.

24-810-0302 Statistical Inference

Credits (H/W for L-T-P) : 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Apply various estimation and testing procedures to deal with real life problems	Apply
2.	Distinguish between point estimation and interval estimation	Analyse
3.	Apply various estimation and testing procedures to deal with real life problems	Apply
4.	Examine unbiasedness, consistency, efficiency, and sufficiency of estimators	Analyse
5.	Illustrate the testing of a statistical hypothesis, to draw valid conclusions	Analyse
6.	Apply large sample and small sample testing procedures and its applications	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2		1	1	2	2	1
CO2	2		2	1	2	3		
CO3	1	2			2	2		
CO4	1	2			3	3		1
CO5	2	1			3	3		2
CO6	2				2	2		2

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Estimation - point estimation; Properties of estimators - unbiasedness, consistency, efficiency, sufficiency; Methods of estimation - method of moments, maximum likelihood method; properties of moment estimator and maximum likelihood estimator, illustrations for different distributions. (15 Hours)

Module 2:

Interval estimation; Confidence interval (CI) - CI for mean of a normal population (3 cases), difference of mean for two normal populations (3 cases), for variance, proportion of success and difference in proportion of success of binomial population. (15 Hours)

Module 3:

Testing of hypothesis - statistical hypotheses, simple and composite hypotheses, two types of errors, significance level, p - value, power of a test, Neyman - Pearson lemma (without proof), most powerful tests. (15 Hours)

Module 4:

Large sample tests, small sample tests, t - test, chi - square test for variance, goodness of fit, independence of attributes. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Casella, G. and Berger, R. L. (2002). *Statistical Inference*, 2^{nd} Edition. Duxbury Advanced Series, USA.

2. Hogg, R.V., Mckean, J. and Craig, A.T. (2018). *Introduction to Mathematical Statistics*, 8^{th} Edition. Pearson, USA.

3. Wasserman, L. (2010). *All of Statistics: A Concise Course in Statistical Inference*, Springer, India.

24-810-0303 Introduction to Statistical Methods

Credits (H/W for L-T-P): 3 (2-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the concept of mathematical expectation and its various properties	Understand
2.	Discuss various generating functions such as PGF, MGF, CGF, CF, and their importance	Understand
3.	Understand different types of modes of convergence	Understand
4.	Evaluate various probability bounds using law of large numbers	Interpret

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2		3	3		
CO2	3			2	3	3		
CO3	3			2	3	3		
CO4	3		2		3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Mathematical expectation - mathematical expectation of a random variable and functions of a random variable, properties of expectation, conditional expectation, important Inequalities. (15 Hours)

Module 2:

Generating Functions - probability generating function, moment generating function, cumulant generating function and characteristic function, properties of generating function. (15 Hours)

Module 3:

Modes of convergence - convergence in probability, convergence in almost sure, convergence in distribution, convergence in r^{th} mean, interrelations. (15 Hours)

Module 4:

Chebychev's inequality, weak law of large numbers, strong law of large numbers, central limit theorems. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Hogg, R. V., McKean, J. W. and Craig, A. T. (2018). *Introduction to Mathematical Statistics*, 8^{th} Edition. Pearson, USA.

Semester IV

Semester Credit: 22 (Major: 16, SEC: 3, VAC: 3); Cumulative Credit: 85								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0401	Discrete Distributions	STAT Major - DSC	24-810-0201	3-0-2	4	50	50	100
24-810-0402	Continuous Distributions	STAT Major - DSC	24-810-0201	3-0-2	4	50	50	100
24-810-0403	Bivariate Data Analysis	STAT Major - DSC	24-810-0101	3-0-2	4	50	50	100
24-810-0404	Sampling Theory and Methods - I	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0405	Statistical Data Analysis Using R - I	SEC	None	1-0-4	3	50	50	100

24-810-0401 Discrete Distributions

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand various discrete distributions	Understand
2.	Demonstrate properties of random variables such as moments, generating functions etc	Apply
3.	Illustrate various applications of the discrete distributions	Analyse
4.	Demonstrate the fitting of distributions - binomial, Poisson	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2		3	3		
CO2	3		2		3	3		
CO3	3		2		3	3		
CO4	3		2		3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Degenerate distribution, uniform distribution on n points, Bernoulli distribution - definitions and examples, properties, transformations. (15 Hours)

Module 2:

Binomial distribution, Poisson distribution - properties, real life applications, additive property, approximation, characterizations, conditional distributions. (15 Hours)

Module 3:

Negative binomial distribution (Pascal or waiting time distribution), geometric distribution - properties, characterizations, real life applications, approximation. (15 Hours)

Module 4:

Hypergeometric distribution - definition, real life applications, approximation; fitting of binomial, Poisson distributions. (15 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Johnson, N. L., Kemp, A. W. and Kotz, S. (2005). *Univariate Discrete Distributions* (Volume 444), 3^{rd} Edition. John Wiley & Sons, New York.

3. Bhuyan, K. C. (2010). *Probability Distribution Theory And Statistical Inference*, New Central Book Agency (P) Limited, India.

24-810-0402 Continuous Distributions

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand various continuous distributions	Understand
2.	Demonstrate properties of random variables such as moments, generating functions etc	Apply
3.	Illustrate various applications of the continuous distributions	Analyse
4.	Demonstrate the fitting of normal distribution	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2		3	3		
CO2	3		2		3	3		
CO3	3		2		3	3		
CO4	3		2		3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Uniform and normal distributions - properties, characterizations, related distributions, approximations. (15 Hours)

Module 2:

Lognormal and Cauchy distributions - properties, related distributions, characterizations, applications. (15 Hours)

Module 3:

Rectangular, exponential, gamma, beta distributions - properties, real life applications, characterizations, related distributions. (15 Hours)

Module 4:

Weibull and Pareto, logistic, extreme value distributions - properties, related distributions, characterizations, applications. (15 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3rd Edition. John Wiley & Sons, India.

References:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Johnson, N. L., Kotz, S. and Balakrishnan, N. (1995). *Continuous Univariate Distributions* (Volume 2), 2^{nd} Edition. John Wiley & Sons, New York.

3. Bhuyan, K. C. (2010). *Probability Distribution Theory and Statistical Inference*, New Central Book Agency (P) Limited, India.

24-810-0403 Bivariate Data Analysis

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand bivariate data and the concept of joint, marginal and conditional probability distributions	Understand
2.	Evaluate and interpret different types of correlation	Interpret
3.	Demonstrate the fundamental concept of linear and nonlinear models	Apply
4.	Analyse bivariate data and understand the concept of association between two variables	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3				3	3		
CO2		3	3		3	3	2	3
CO3	3		3		3	3	3	
CO4	3		3		3	3	3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Bivariate data - definition, scatter diagram, joint, marginal and conditional distributions (discrete and continuous). (15 Hours)

Module 2:

Correlation - types of correlation, Karl Pearson's coefficient of correlation for grouped and ungrouped data and its properties, Spearman's rank correlation, ϕ coefficient, Cramers's V, Kendall's τ, measures using discordant and concordant pairs, point biserial correlation, interpretation of correlation coefficient, visualization of variables from different scales. (15 Hours)

Module 3:

Regression - lines of regression, regression coefficients, properties of regression coefficients, correlation versus regression; Curve fitting - principle of least squares, fitting of straight line, polynomial of n^{th} degree, exponential curve and power curves using the principle of least squares. (15 Hours)

Module 4:

Illustration with specific examples and numerical exercises using statistical packages. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

References:

1. Heumann, C. and Shalabh, M.S. (2016). *Introduction to Statistics and Data Analysis*, 1^{st} Edition. Springer, India.
2. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2016). *Fundamentals of Statistics* (Volume 2), 4^{th} Edition. The World Press Private Limited, India.
3. Mukhopadhyay, P. (2019). *Applied Statistics*, 2^{nd} Edition. Books and Allied (P) Ltd, India.

24-810-0404 Sampling Theory and Methods - I

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Classify census, sampling and recognize the organization and execution of large sample surveys	Understand
2.	Practice the preparation of questionnaires	Apply
3.	Compute estimators for population parameters for quantitative and qualitative data	Apply
4.	Distinguish stratified, systematic and circular systematic sampling methods	Understand
5.	Compute sample estimators under cluster sampling	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2		2				
CO2	2			2				
CO3		2	2			2		
CO4		2	2			2		
CO5			2			2		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Census and sampling, principal steps in sample survey, probability sampling, judgment sampling, organization and execution of large sample surveys, sampling and non - sampling errors, preparation of questionnaire, estimation of sample size. (10 Hours)

Module 2:

Simple random sampling with and without replacement - methods of collecting simple random samples, unbiased estimate of the population mean and population total, their variances and estimate of these variances, simple random sampling for proportions. (20 Hours)

Module 3:

Stratified random sampling - estimation of population mean and total, proportional and Neyman allocation of sample sizes, optimum allocation considering cost; Systematic sampling - linear and circular systematic sampling, comparison with simple random sampling. (20 Hours)

Module 4:

Cluster sampling: Clusters with equal sizes - estimation of the population mean and total, comparison with simple random sampling; Two stage cluster sampling - estimate of variance of population mean. (10 Hours)

Text Books:

1. Gupta, S.C. and Kapoor, V.K. (2014). *Fundamentals of Applied Statistics*, 4^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Bansal, A. (2017). *Survey Sampling*, Narosa Publishing House Pvt Ltd, India.

References:

1. Murthy, M.N. (1967). *Sampling Theory and Methods*, Statistical Publishing Society, Calcutta.

2. Mukhopadhyay, P. (2008). *Theory and Methods of Survey Sampling*, 2^{nd} Edition. PHI Learning Pvt Ltd, New Delhi.

3. Arnab, R. (2017). *Survey Sampling Theory and Applications*, Academic Press.

4. Singh, D. and Chaudhary, F.S. (2020). *Theory and Analysis of Sample Survey Designs*, 2^{nd} Edition. New Age International Private Limited, New Delhi.

5. Cochran, W. G. (2007). *Sampling Techniques*, 3^{rd} Edition. Wiley India Pvt. Ltd, India.

6. Sampath, S. (2005). *Sampling Theory and Methods*, 2^{nd} Edition. Alpha Science International Ltd, U. K.

24-810-0405 Statistical Data Analysis Using R - I

Credits (H/W for L-T-P): 3 (1-0-4)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	To understand the basics in R programming in terms of constructs, control statements, string functions	Understand
2.	Create matrices, arrays and lists using R	Create
3.	Import a variety of data formats into R using R Studio	Apply
4.	Apply critical programming language concepts such as data types, iteration, control structures, functions, and boolean operators by writing R programs and through examples	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1				2	2	3	3
CO2		2	2		1	1	3	3
CO3		3	3		2	2	3	3
CO4	3	1	1		2	2	3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introducing to R - R Data Structures, installing and loading packages, setting up your working directory, downloading and importing data, working with missing data, extracting a subset of a dataframe, writing R scripts, adding comments and documentation, creating reports, Help functions in R, vectors, scalars, declarations, recycling, common vector operations, using all and any, vectorized operations, NA and NULL values, filtering, vectorized if - then else, vector equality, vector element names. (15 Hours)

Module 2:

Matrices, arrays and lists, creating matrices, matrix operations, applying functions to matrix rows and columns, adding and deleting rows and columns, vector/matrix distinction, avoiding dimension reduction, higher dimensional arrays; Lists – creating lists, general list operations, accessing list components and values, applying functions to lists, recursive lists. (15 Hours)

Module 3:

Creating dataframes, matrix like operations in frames, merging dataframes, applying functions to dataframes; Factors and tables, factors and levels, common functions used with factors, working with tables, other factors and related functions. (15 Hours)

Module 4:

Iteration - while loops, for loops, control statements, arithmetic and Boolean operators and values, default values for arguments, returning Boolean values, functions are objects, environment and scope issues, writing upstairs, recursion, replacement functions, tools for composing function code, math and simulations in R, creating graphs, customizing graphs, saving graphs to files, creating three dimensional plots. (15 Hours)

Text Books:

1. Matloff, N. (2011). *The Art of R Programming: A Tour of Statistical Software Design*, 1^{st} Edition. No Starch Press, US.

2. Crawley, M. J. (2012). *The R Book*, 2^{nd} Edition. John Wiley & Sons, U. K.

References:

1. Jones, O., Maillardet. R. and Robinson, A. (2014). *Introduction to Scientific Programming and Simulation Using R*, 2^{nd} Edition. Chapman & Hall/CRC, USA.

2. Lander, J. P. (2013). *R for Everyone: Advanced Analytics and Graphics*, 1^{st} Edition. Pearson Addison - Wesley Professional, USA.

3. Gardener, M. (2013). *Beginning R – The Statistical Programming Language*, John Wiley & Sons, USA.

4. Knell, R. J. (2014). *Introductory R: A Beginner's Guide to Data Visualisation, Statistical Analysis and Programming in R*, Robert Knell.

5. Wickham, H. and Grolemund, G. (2023). *R for Data Science*, 2^{nd} Edition. O'Reilly Media, Inc, U. S. (Available for free at http://r4ds.had.co.nz, http://r4ds.hadley.nz/.)

Semester V

Semester Credit: 23 (Major: 20, SEC: 3); Cumulative Credit: 108								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0501	Statistical Inference - I	STAT Major - DSC	24-810-0201/0202	3-0-2	4	50	50	100
24-810-0502	Statistical Quality Control	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0503	Operations Research - I	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0504	Time Based Data and Index Numbers	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-05xx	Elective - I	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0508	Statistical Data Analysis Using Python	SEC	None	1-0-4	3	50	50	100
Elective - I (Choose any one course)								
24-810-0505	Machine Learning	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0506	Actuarial Statistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0507	Financial Statistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100

24-810-0501 Statistical Inference - I

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe various sampling distributions	Understand
2.	Relate various sampling distributions	Understand
3.	Differentiate desirable properties of good estimators	Analyse
4.	Differentiate the problem of point and interval estimators	Analyse
5.	Evaluate the estimators of parameters of various distributions by employing various approaches	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2			2		2	2
CO2	2	3						1
CO3			3	2	2	3	2	2
CO4		2		2	1	3	1	2
CO5		3		3	2	3	2	1

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Population, sample, parameter and statistic, parameter space, sampling distributions, concept of random sampling and statistic, definition of sampling distribution, standard error, sampling distribution of the mean and variance of a sample arising from a normal distribution; Chi-square distribution - properties and applications; Student's t distribution - properties and applications; Snedecor's F distribution - properties and applications; Interrelationships between standard normal, Chi-square, t, and F distributions. (17 Hours)

Module 2:

Problems of statistical inference - estimate and estimator; point and interval estimation; Desirable properties of estimators - unbiasedness, consistency, efficiency and sufficiency. (15 Hours)

Module 3:

Interval estimation, confidence interval, confidence coefficient; Constructing confidence intervals - mean, variance, proportion of a population, difference of means and the difference of proportion of two populations. (13 Hours)

Module 4:

Methods of estimation: Method of moments – examples, properties of moment estimator (statement only); Method of maximum likelihood -properties of likelihood estimator (statement only); method of least-squares and minimum variance bound unbiased estimator. (15 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

2. Kale, B. K. (2005). *A First Course on Parametric Inference*, 2^{nd} Edition. Alpha Science International, India.

References:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Mukhopadhaya, P. (2006). *Mathematical Statistics*, 3^{rd} Edition. Books and Allied Pvt. Ltd., Kolkata.

3. Casella, G. and Berger, R. L. (2002). *Statistical Inference*, 2^{nd} Edition. Duxbury Advanced Series, USA.

24-810-0502 Statistical Quality Control

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Differentiate various types of control charts for variables	Apply
2.	Differentiate various types of control charts for attributes	Apply
3.	Analyse process and measurement system capability	Analyse
4.	Apply various types sampling plans for attributes and their measures of performance	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		2	3			2	2	2
CO2		2	3			2	2	
CO3			3			3	3	
CO4		2	1			2	2	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Control charts for variables: Control charts for $\bar{x}$ and R - development and use of $\bar{x}$ and R, interpretation of $\bar{x}$ and R charts, effect of nonnormality on $\bar{x}$ and R charts, operating characteristic function, average run length for the $\bar{x}$ chart; Control charts for $\bar{x}$ and s - construction and operation of $\bar{x}$ and s charts, $\bar{x}$ and s control charts with variable sample size, s^2 control chart. (15 Hours)

Module 2:

Control charts for attributes: Control chart for fraction nonconforming, development and operation of the control chart, variable sample size, operating-characteristic function and average run length calculations; Control charts for nonconformities (defects) - procedures with constant sample size, procedures with variable sample size; choice between attributes and variables control charts. (15 Hours)

Module 3:

Process and measurement system capability analysis - process capability analysis using a histogram or a probability plot, process capability ratios, use and interpretation of C_p, process capability ratio for an off-center process, normality and the process capability ratio, process centering, confidence intervals and tests on process capability ratios, process capability analysis using a control chart, process capability analysis using designed experiments, process capability analysis with attribute data. (15 Hours)

Module 4:

Acceptance sampling plans - acceptance sampling by variables, sampling plans for a single specification limit with known and unknown variance, sampling plans with double specification limits, comparison of sampling plans by variable and attributes. (15 Hours)

Text Books:

1. Montgomery, D. C. (2019). *Introduction to Statistical Quality Control*, 8^{th} Edition. Wiley, New Jersey.

References:

1. Mittag, H. J. and Rinne, H. (1993). *Statistical Methods for Quality Assurance*, 2^{nd} Edition. CRC Press, USA Chapters 1, 3 and 4, 15.
2. Schilling, E. G. and Neubauer D. V. (2017). *Acceptance Sampling in Quality Control*, 3^{rd} Edition. CRC Press, USA.
3. Mitra, A. (2001). *Fundamentals of Quality Control and Improvement*, Pearson Education, Asia, Chapter 12 (relevant parts).
4. Duncan, A.J. (1986). *Quality control and Industrial Statistics*, 5^{th} Edition. Richard D. Irwin, Illinois.
5. Grant E. L. and Leavenworth, R. S. (2017) *Statistical Quality Control*, 7^{th} Edition. McGraw Hill Education, India.
6. Cho, Chin-Kuei (1987). *Quality Programming: Developing and Testing Software With Statistical Quality Control*. John Wiley & Sons, New Jersey.

24-810-0503 Operations Research - I

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Practice mathematical formulation of the linear programming problem	Apply
2.	Solve the linear programming problem using, graphical, simplex, big-M and two-phase methods	Apply
3.	Use the duality in LPP, its applications and dual simplex method	Apply
4.	Differentiate the methods of solving transportation and assignment problems	Analyse
5.	Distinguish basic components of network scheduling	Understand
6	Differentiate PERT and CPM	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2		2				3		
CO3		2				2		
CO4	3					2		
CO5	2					2		
CO6		2		2				

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Linear programming problem (LPP) – mathematical formulation, graphical solution, simplex method and its computational procedure; Use of artificial variables – two phase and big-M methods. (20 Hours)

Module 2:

Duality in LPP, primal-dual problem, duality theorems, duality and simplex method, econometric interpretation of duality, dual simplex method. (15 Hours)

Module 3:

Transportation problem (TP) - LP formulation, initial basic feasible solution, test for optimality, degeneracy in TP, MODI and stepping stone methods, time minimization of TP; Assignment problem - solution methods and special cases. (15 Hours)

Module 4:

Network scheduling - basic components, critical path analysis, probability considerations in PERT. (10 Hours)

Text Books:

1. Swarup, Kanti, Gupta, P. K. and Mohan, Man. (2022). *Operations Research*, 20^{th} Edition. Sultan Chand & Sons, New Delhi.

References:

1. Hillier, F. S. and Lieberman, G. (2012). *Introduction to Operations Research*, 9^{th} Edition. McGraw-Hill Education, New Delhi.
2. Pundir, S. K. (2020). *Operations Research*. CBS Publishers & Distributors, New Delhi.

24-810-0504 Time Based Data and Index Numbers

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Calculate different types of index numbers and their constructions	Analyse
2.	Test index numbers using various tests	Analyse
3.	Apply the concepts of time series and obtain trend and seasonal indices	Apply
4.	Apply the time series method to predict the future of a problem in a concern	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	3			3	3	2	
CO2	3				3	3	2	
CO3		3		2	3	3	3	3
CO4		3		2	3	3	3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction, components of time series, mathematical models for time series, uses of time series; Measurements of trend - graphic method, method of semi-averages, method of curve fitting by principle of least squares, growth curves and their fitting, moving average method, approximation to moving averages. (15 Hours)

Module 2:

Measurement of seasonal variations - method of simple averages, ratio to trend method, ratio to moving average method, link relative method, de-seasonalisation of data; Forecasting by smoothing methods - moving averages, weighted moving averages, exponential smoothing methods. (15 Hours)

Module 3:

Introduction & definition, basic problems involved in the construction of index numbers; Construction of index numbers - simple (unweighted) aggregate methods, weighted aggregate methods, average of price relatives, chain base method (chain indices); Criteria for a good index number - unit test, time reversal test, factor reversal test, circular test. (15 Hours)

Module 4:

Classification of index numbers, wholesale price index number, cost of living index number, consumer price indices (CPI) - Indian scenario, base shifting, splicing and deflating of index numbers, index of industrial production (IIP) - Indian scenario, index of agricultural production, uses of index numbers, limitations of index numbers. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2014). *Fundamentals of Applied Statistics*, 4^{th} Edition. Sultan Chand and Sons, New Delhi.

References:

1. Gupta, S. P. (2021). *Statistical Methods*, 46^{th} Edition. Sultan Chand and Sons, New Delhi.
2. Elhance, D. N., Elhance V. and Aggarwal B. M. (2018). *Fundamentals of Statistics*. Kitab Mahal, New Delhi.

24-810-0508 Statistical Data Analysis Using Python

Credits (H/W for L-T-P): 3 (1-0-4)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1	Students will demonstrate a solid understanding of Python fundamentals and statistical concepts	Understand
2	Students will be able to apply Python programming skills to manipulate and Analyse data using NumPy, Pandas, and other relevant libraries	Apply
3	Students will Analyse and interpret data using descriptive statistics, correlation, regression, and hypothesis testing	Analyse
4	Students will create Python-based solutions to statistical problems and effectively communicate findings	Create

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1	2	2		2	2	1	2
CO2		2			2	1		3
CO3	2	2	2		2	1	1	2
CO4	1	2	1	1	2	1		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to Python for statistics - overview of Python in statistical analysis, setting up Python environment (Anaconda, Jupyter Notebooks), introduction to Jupyter notebooks for interactive coding; Python basics - variables, assignments data types (integers, floats, strings), data structures, arithmetic operations, expressions, objects and classes, conditionals and loops. (15 Hours)

Module 2:

Data manipulation with NumPy and Pandas: NumPy basics - arrays and matrices, mathematical operations with arrays; Pandas fundamentals - series and data frames, data indexing and selection, loading and saving data with Pandas; data extraction, cleaning, integration, annotation, reduction, transformation, EDA, data pre-processing, handling quantitative and qualitative values. (20 Hours)

Module 3:

Descriptive statistics with Python: Measures of central tendency - mean, median, mode; Measures of dispersion - range, variance, standard deviation; frequency distributions and histograms; Visualization of descriptive statistics using Matplotlib & Seaborn - histograms, scatter plots, box plots, stem and leaf diagram, qq plot and summary statistics visualization, time series plots. (15 Hours)

Module 4:

Correlation and regression analysis: Calculating correlation coefficients - Pearson, Spearman; Simple linear regression - least squares method; Multiple linear regression - interpretation of coefficients; visualization of relationships using scatter plots, heat map and regression lines. (10 Hours)

Text Books:

1. Igual, L. and Seguí, S. (2017). *Introduction to Data Science - A Python Approach to Concepts, Techniques and Applications*. Springer, New York.

2. Raschka, S. (2019). *Python Machine Learning*, 3rd Edition. Packt Publishing, United Kingdom.

References:

1. Summerfield, M. (2008). *Programming in Python 3: A Complete Introduction to the Python Language*, 1st Edition. Addison Wesley, United Kingdom.

2. Park, A. (2021). *Python for Data Analysis: The Ultimate Guide for Beginners to Master Data Analysis and Analytics with Python Using Pandas, Numpy and Ipython*, 2nd Edition. Eureka Online Ltd, United Kingdom.

Semester VI

Semester Credit: 23 (Major: 20, SEC: 3); Cumulative Credit: 131								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0601	Statistical Inference - II	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0602	Design and Analysis of Experiments - I	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0603	Multivariate Methods	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0604	Survival Analysis	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-06xx	Elective - II	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0608	Statistical Data Analysis Using R - II	SEC	24-810-0508	1-0-4	3	50	50	100
Elective - II (Choose any one course)								
24-810-0605	Introduction to Data Mining	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0606	Econometrics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	0-2-0	4	50	50	100
24-810-0607	MOOC	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	0-2-0	4	-	100	100
Internship (Not counted as a course): 2 credits								

24-810-0601 Statistical Inference - II

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Differentiate hypothesis and statistical hypothesis	Understand
2.	List the basic concepts behind the statistical testing problem	Remember
3.	Solve the given statistical testing problem and arrive at a conclusion	Apply
4.	Differentiate the use of various tests based on chi - square distribution	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1	2		1	2		3	
CO2	3		3	2	2		2	
CO3			3	3	3			
CO4		2			1		3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Statistical hypothesis - simple and composite, null and alternative hypothesis; Two types of errors - type I error and type II error; level of significance, size and power of a test, critical region, power curve, power function and p - value. (15 Hours)

Module 2:

Large sample tests - testing the significance of a mean, testing the equality of two means, testing the significance of a proportion, testing the equality of two proportions, testing the significance of correlation coefficient, testing the significance of the difference between two correlation coefficients. (15 Hours)

Module 3:

Small sample tests: Tests based on Student's t distribution – test of significance of mean from a normal population, testing the equality of means of two normal populations, testing the significance of correlation coefficient, paired t test. (15 Hours)

Module 4:

Tests based on chi – square distribution - testing the goodness of fit, testing the independence of attributes, testing the significance of standard deviation of a normal population; Tests based on F distribution – testing the equality of variances of two normal populations. (15 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3rd Edition. John Wiley & Sons, India.

2. Kale, B. K. (2005). *A First Course on Parametric Inference*, 2nd Edition. Alpha Science International, India.

References:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12th Edition. Sultan Chand & Sons, New Delhi.

2. Mukhopadhaya, P. (2006). *Mathematical Statistics*, 3rd Edition. Books and Allied Pvt. Ltd., Kolkata.

3. Casella, G. and Berger, R. L. (2002). *Statistical Inference*, 2nd Edition. Duxbury Advanced Series, USA.

24-810-0602 Design and Analysis of Experiments - I

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify the concepts of linear estimation, analysis of variance, two - way orthogonal and non-orthogonal data	Understand
2.	Identify one - way and two - way classifications	Understand
3.	Analyse one - way, two - way classifications, experiments with covariance and model adequacy checking procedures	Analyse
4.	Apply methods of analysing different types of basic designs of experiments and analysis of covariance	Apply
5.	Discuss factorial experiments and incomplete block designs	Understand
6	Apply methods of analyzing factorial experiments and incomplete block designs	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2			3	2				
CO3		2	3	2				
CO4		2	3					
CO5	2		3	2				
CO6	2		2					

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Linear estimation, estimability of parametric functions; Analysis of variance – assumptions of ANOVA test, one - way and two - way classified data (with single observation per cell) and their analysis and estimation; analysis of two - way orthogonal data, analysis of non - orthogonal two - way data, analysis of fixed and random effects models. (20 Hours)

Module 2:

Model adequacy checking, contrasts and orthogonal contrasts, comparing pairwise treatment means, principles of experimentation; Design and analysis of CRD & RBD – fixed and random effects; missing values. (18 Hours)

Module 3:

Latin square design, missing plot technique, comparison of efficiency, Graeco - Latin square design, analysis of covariance with a single observation per cell. (12 Hours)

Module 4:

Basic concepts of factorial experiments, 2^2 and 2^3 factorial experiments, basic concepts of Incomplete block design, balanced incomplete block design. (10 Hours)

Text Books:

1. Montgomery, D C. (2019). *Design and Analysis of Experiments*, 10^{th} Edition. John Wiley & Sons.
2. Das, M.N. and Giri, N.C. (2017). *Design and Analysis of Experiments*, New Age Publishers, New Delhi.

References:

1. Gupta, S.C. and Kapoor, V.K. (2014). *Fundamentals of Applied Statistics*, 4^{th} Edition. Sultan Chand & Sons, New Delhi.
2. Joshy, D.D. (2020). *Linear Estimation and Design of Experiments*, 2^{nd} Edition. New Age International Pvt. Ltd, India.

24-810-0603 Multivariate Methods

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe various plots for multivariate data	Understand
2.	Find marginal and conditional distribution of multivariate distributions.	Evaluate
3.	Describe different multivariate distributions and its properties	Understand
4.	Analyse categorical data and make conclusion from it	Analyse
5.	Distinguish between partial and multiple correlation	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1		2			1	1	
CO2	1		2			1	1	
CO3	1		2			1	1	
CO4	1		2			1	1	
CO5	1		2			1	1	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Multivariate data visualization - mosaic plots, scatter plot matrix, bivariate qq - plots, spider web plots, DD Plots, parallel coordinate plots, trellis displays. (10 Hours)

Module 2:

Multivariate probability distribution - mean vector and covariance matrix, marginal and conditional distribution, ellipsoid of concentration; Standard multivariate probability distributions - multivariate normal, multinomial, Dirichlet distributions, their properties and related results. (20 Hours)

Module 3:

Analysis of categorical data - contingency table, independence and association of attributes, measure of association - odds ratio, Pearson's and Yule's measure. (15 Hours)

Module 4:

Descriptive measures on multivariate data - multiple correlations, partial correlation, relationship between higher order and lower order partial correlations, related problems and inequalities. (15 Hours)

Text Books:

1. Anderson, T. W. (2009). *An Introduction to Multivariate Statistical Analysis (Chapter-2)*, 3rd Edition. John Wiley & Sons, India.

2. Johnson, R. A. and Wichern, D. W. (2023). *Applied Multivariate Statistical Analysis*, 6th Edition. Pearson, London.

References:

1. Alan, A. (2007). *An Introduction to Categorical Data Analysis*, 2nd Edition. John Wiley & Sons, New Jersey.

2. Hardle, W. and Simar, L. (2019). *Applied Multivariate Statistical Analysis*, 5th Edition. Springer, Switzerland.

3. Kendall, M. G., & Alan, S. (1961). *The Advanced Theory of Statistics*. Vols. I (Ch. 15) and II (Ch26, 27). Charles Griffin.

4. Rao, C. R. (1974). *Linear Statistical Theory and its Applications*, (Chapter-4 & 8), Wiley Eastern.

5. Wilks, S.S. *Mathematical Statistics (Chapter 6)*. John Wiley.

24-810-0604 Survival Analysis

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the basic concepts and ideas of survival analysis	Understand
2.	Understand the statistical techniques for survival data	Understand
3.	Examine the properties and methods for standard survival time distributions	Analyse
4.	Estimate survival functions using parametric and non - parametric methods	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3			1	2	2		
CO2	2		1		3	1	2	
CO3	1				2	1		
CO4	2		2		1		1	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to survival analysis survivor function, hazard function, cumulative hazard function, density function and their relationships for both continuous and discrete survival times. (15 Hours)

Module 2:

Censoring - type 1 censoring, type 2 censoring, left and right censoring, interval censoring, progressive censoring; left Truncation, right truncation. (15 Hours)

Module 3:

Parametric survival models - normal distribution, exponential distribution, Weibull Distribution, log normal distribution, extreme value distribution, Gompertz distribution, basic properties. (15 Hours)

Module 4 :

Non - parametric estimation and graphical methods - Kaplan - Meier estimator, Nelson - Aalen estimator, and their variance estimators; log - rank test for distribution difference, graphical methods that combine nonparametric estimation. (15 Hours)

Text Books:

1. Klein, J. P. and Moeschberger, M.L. (2005). *Survival Analysis - Techniques for Censored and Truncated Data*, 2^{nd} Edition. Springer - Verlag New York Inc, Germany.

References:

1. Hosmer, D. W., Lemeshow, S., and May, S. (2008). *Applied Survival Analysis: Regression Modeling of Time - to - Event Data*, 2^{nd} edition. Wiley - Interscience, United Kingdom.
2. Collett, D. (2023). *Modelling Survival Data in Medical Research*, 4^{th} edition. Chapman and Hall/CRC, New York.

24-810-0608 Statistical Data Analysis Using R - II

Credits (H/W for L-T-P): 3 (1-0-4)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Analyse various measures of central tendency, dispersion, skewness, kurtosis and correlation by R	Analyse
2.	Visualize data attributes using ggplot2 and other R packages	Analyse
3.	Create documents, presentations, websites etc. using R	Create
4.	Apply the R programming from a statistical perspective	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	3	2		1	3	2	3
CO2		3	3		1	3	2	3
CO3		3	3		1	3	2	3
CO4		3	3	2	1	3	2	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Measures of central tendency, measures of variability, skewness and kurtosis, summary functions, describe functions, and descriptive statistics by group, correlation. (15 Hours)

Module 2:

Scatter plots, box plots, scatter plots and box and whisker plots together, histograms; Messy data - renaming columns (variable names) , attaching / detaching; Tabulating data - constructing simple frequency tables, ordering factor variables. (15 Hours)

Module 3:

Using the ggplot2 package to visualize data - applying themes from ggthemes to refine and customize charts and graphs; building data graphics for dynamic reporting, writing SQL statements in R, using the Select, From, Where, Is, Like, Order By, Limit, Max, Min SQL functions, interfacing R to other languages, parallel R. (20 Hours)

Module 4:

R Markdown basics - text formatting, code chunks, YAML header, preview of notebooks, presentations, websites, and dashboards, basic statistics. (10 Hours)

Text Books:

1. Matloff, N. (2011). *The Art of R Programming: A Tour of Statistical Software Design*, 1^{st} Edition. No Starch Press, US.

2. Crawley, M. J. (2012). *The R Book*, 2^{nd} Edition. John Wiley & Sons, U. K.

References:

1. Wickham, H. and Grolemund, G. (2023). *R for Data Science*, 2^{nd} Edition. O'Reilly Media, Inc, U. S. (Available for free at http://r4ds.had.co.nz, http://r4ds.hadley.nz/.)

2. Lander, J. P. (2013). *R for Everyone: Advanced Analytics and Graphics*, 1^{st} Edition. Pearson Addison - Wesley Professional, USA

3. Gardener, M. (2013). *Beginning R – The Statistical Programming Language*, John Wiley & Sons, USA.

4. Knell, R. J. (2014). *Introductory R: A Beginner's Guide to Data Visualisation, Statistical Analysis and Programming in R*, Robert Knell.

List of Electives for V/VI Semesters

24-810-0505 Machine Learning

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the essential concepts and methods in Statistical Machine Learning	Understand
2.	Apply machine learning techniques, including linear regression, logistic regression, and support vector machines, to real-world problems	Apply
3.	Analyse the performance of machine learning models, including assessing bias-variance trade-offs, overfitting, and the impact of regularization	Analyse
4.	Develop and present solutions to real-world problems using a variety of machine learning techniques	Create

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		2			2	1	1	1
CO2	1	2			3	1	2	3
CO3	2	2	3		3			
CO4			3	1	3	1	2	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Overview of machine learning and its applications, the distinction between supervised, unsupervised, and semi-supervised learning, simple and multiple linear regression, model fitting, parameter estimation, and hypothesis testing; Model assessment and selection - bias-variance trade-off and overfitting; cross-validation and its application in model selection, performance metrics for classification and regression tasks. (20 Hours)

Module 2:

Linear methods for classification: Logistic regression for binary classification; Multiclass classification using one-vs-rest and one-vs-one approaches; maximum likelihood estimation and decision boundaries, basis expansion; Regularization and Kernel Methods - Feature transformation and basis expansion techniques; regularization methods (L1, L2) for improving model robustness, kernel methods for nonlinear classification and regression. (20 Hours)

Module 3:

Support vector machines - maximum margin classifiers and support vector classification, nonlinear separation using kernel trick, soft - margin classification and handling outliers; Tree - based methods and boosting - decision tree construction and split criteria, ensemble learning with bagging and boosting, introduction to random forests and gradient boosting. (10 Hours)

Module 4:

Unsupervised learning - clustering algorithms (K-means, hierarchical clustering), density estimation with Gaussian mixture models (GMM), recursive feature elimination, principal component analysis (PCA) for dimensionality reduction. (10 Hours)

Text Books:

1. Alpaydin, E. (2020). *Introduction to Machine Learning*, 4^{th} Edition. MIT Press, USA.
2. Witten, D., James, G., Hastie, Trevor and Tibshirani, Robert. (2013). *An Introduction to Statistical Learning with Applications in R*, 1^{st} Edition. Springer, New York.

References :

1. Deisenroth, M. P., Faisal, A. A., and Ong, C. S. (2020). *Mathematics for Machine Learning*. Cambridge University Press, United Kingdom.
2. Hardt, M., & Recht, B. (2022). *Patterns, Predictions, and Actions: Foundations of Machine Learning*. Princeton University Press, US.

24-810-0506 Actuarial Statistics

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Analyse the stochastic behaviour of the insurance industry	Analyse
2.	Evaluate the statistical methods for actuarial data	Evaluate
3.	Understand the actuarial present values or benefits in life insurance products	Understand
4.	Analyse the concept of annuities and reserves	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2			2	2		1
CO2	1	1						
CO3	2	1	2		2		2	
CO4	3	2			1		1	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Insurance business - introduction, insurance companies as business organizations, concept of risk - failure lifetime distributions and life tables, future lifetime random variable, curtate future lifetime, life tables. (15 hours)

Module 2:

Actuarial present values or benefit in life insurance products, compound interest and discount factor, benefit payable at the moment of death, benefit payable at the end of year of death – relation between these quantities. (15 hours)

Module 3:

Annuities - annuities certain, continuous life annuities, discrete life annuities, life annuities with monthly payments, premiums- Loss at issue random variable, fully continuous premiums, fully discrete premiums. (15 hours)

Module 4:

Reserves - fully continuous reserves, fully discrete reserves; Multiple life contracts - joint life status, last survivor status. (15 hours)

Text Books:

1. Desmukh S. R. (2009). *Actuarial Statistics - An Introduction Using R*, 3^{rd} Edition. Universities Press (India) Private Ltd., Hyderabad.

References:

1. Promislow, S. D. (2006). *Fundamentals of Actuarial Mathematics*, John Wiley, Chapters 2-11 and 14.

2. Dickson, C. M. D. (2016). *Insurance Risk and Ruin*, 2^{nd} Edition. Cambridge University Press, United Kingdom.

3. Bowers, N. L., Gerber, H. U., Hickman, J. C., Jones, D. A. And Nesbitt, C. J. (1997). *Actuarial Mathematics*, 2^{nd} Edition. Society Of Actuaries, Illinois.

24-810-0507 Financial Statistics

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Explain fundamental concepts of statistical terminology related to financial data analysis	Understand
2.	Identify suitable stochastic models for financial data	Analyse
3.	Understand the intricacies of the pricing derivatives and analyse them quantitatively	Understand
4.	Use the tools needed for option pricing	Application
5.	Analyse different option pricing models	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1	2		2		2	2	
CO2	1	2		2		2	2	
CO3	1	2		2		2	2	
CO4	1	2		2		2	2	
CO5	1	2		2		2	2	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Basic concepts of probability theory - random variables, expectation and moments, skewness and kurtosois, random vectors, dependence, correlation, conditional probabilities; Stochastic processes in discrete time - binomial processes, general random walks, geometric random walks, binomial models with state dependent increments. (15 Hours)

Module 2:

Introduction to derivatives - forward contracts, spot price, forward price, future price; call and put options, zero-coupon bonds and discount bonds; Pricing Derivatives - arbitrage relations and perfect financial markets, pricing futures, put-call parity for European options, relationship between strike price and option price; Discrete time process - binomial model with period one. (15 Hours)

Module 3:

Tools needed for option pricing - continuous time process - geometric Brownian motion, Wiener process, stochastic integration and stochastic differential equations, stock price as a stochastic process, Ito's lemma. (15 Hours)

Module 4:

Black-Scholes option pricing model - Black-Scholes differential equation, Black-Scholes formula for European options; Hedging portfolios - delta, gamma and theta hedging; Binomial model for European options - Cox-Ross-Rubinstein approach to option pricing; Discrete dividends. (15 Hours)

Text Books:

1. Franke, J., Hardle, W. K. and Hafner, C. M. (2019). *Statistics of Financial Markets*, 5^{th} Edition. Springer, Switzerland.

References:

1. Steland, Ansgar (2012). *Financial Statistics and Mathematical Finance: Methods, Models and Applications*. Wiley, New Jersey.
2. Lindstrom E., Madsen, H., and Nielsen J. N. (2019). *Statistics for Finance*. CRC Press, India.
3. Elliott, R. J. and Kopp, P. E. (2004). *Mathematics of Financial Markets*, 2^{nd} edition, Springer, New York.
4. Stanley L. S. (2012). *A Course on Statistics for Finance*, 1^{st} Edition. CRC Press, Florida.
5. Shreve, S. E. (2004). *Stochastic Calculus for Finance I - The Binomial Asset Pricing Model*, Springer, New York.
6. Mishura, Y. (2016). *Financial Mathematics*, ISTE Press Ltd - Elsevier Inc, London.

24-810-0605 Introduction to Data Mining

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand basic ideas of data mining	Understand
2.	Analyse the tools in data mining in a statistical perspective	Analyse
3.	Explore data using visualization methods	Analyse
4.	Familiarize data preprocessing methods	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	1				2	1	
CO2		2				2		1
CO3		2				1		3
CO4		3				3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Data mining - what is data mining, motivating challenges, scalability, high dimensionality, heterogeneous and complex data, data ownership and distribution, non - traditional analysis, origin of data mining; Data mining tasks - predictive task, descriptive task, predictive modeling, association analysis, anamoly detection. (20 Hours)

Module 2:

Data - types of data, attributes and measurements, data quality, data pre - processing, dicsretization and binarization, variable transformation, measures of similarity and dissimilarity, proxy measures and examples. (15 Hours)

Module 3:

Exploring Data - summary statistics, visualization, OLAP and multidimensional data analysis, major tasks in data preprocessing, data cleaning, data integration, data reduction, data transformation, dimensionality reduction and pivoting. (10 Hours)

Module 4:

Data Preprocessing - classification, basic concepts and preliminaries, general approach to solve a classification problem, decision trees, model overfitting, model evaluation, methods for comparing classifiers. (15 Hours)

Text Books:

1. Han, J., Pei, J. and Tong, H. (2022). *Data Mining: Concepts and Techniques*, 4^{th} Edition. Morgan Kaufmann Publishers In, India.

References:

1. Tan, P.N., Steinbach, M., Karpatne A. and Kumar, V. (2021). *Introduction to Data Mining*, 2^{nd} Edition. Pearson, London.

24-810-0606 Econometrics

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the importance of the relation between econometric analysis and economic theory	Understand
2.	Analyse the simple and multiple linear regression models	Analyse
3.	Explain the auto - regressive and distributed lag models	Evaluate
4.	Develop simultaneous equation models to represent the interdependent relationship between variables	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1	2				2	2	
CO2	1	2				2	2	
CO3	1	2				2	2	
CO4	1	2				2	2	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Nature of econometrics and economic data - definition of econometrics, steps in empirical economic analysis, econometric model, the role of measurement in economics; The structure of economic data - cross - sectional data, time series data, pooled cross - section data, panel data. (10 Hours)

Module 2:

Simple regression model: Two variable linear regression model - assumptions, estimation of parameters, tests of significance and properties of estimators; Functional forms of Regression models – log - linear models, semi - log models and reciprocal models, choice of functional form; The general linear model - review of assumptions, estimation and properties of estimators, unbiasedness, BLUEs and tests of significance of estimates, analysis of variance; Dummy variables - nature of dummy variables, use of dummy variables, errors in variables and its consequences. (20 Hours)

Module 3:

Auto - regressive and distributed lag models: introduction; Types of lag schemes - Koyck's lag model, Almon's lag scheme, partial adjustment and expectations models; Causality in economics – the Granger causality Test. (15 Hours)

Module 4:

Simultaneous equation models - specification, simultaneous bias, inconsistency of OLS estimators, the concept of identification, rank and order conditions for identification, indirect least squares, two stage least squares (without proof), problems. (15 Hours)

Text Books:

1. Johnston, J. (1996). *Econometric Methods*, 4^{th} Edition. McGraw - Hill Education, New York.
2. Gujarathi, D.N, Porter, D.C., and Gunasekar, S. (2017). *Basic Econometrics*, 5^{th} Edition. McGraw Hill Education, India.

References:

1. Maddala, G.S. and Lahiri, K. (2012). *Introduction to Econometrics*, 4^{th} Edition. John Wiley & Sons, New York.
2. Tintner, G. (2013). *Econometrics*, Literary Licensing LLC, US.
3. Wooldridge, J. M. (2022). *Introductory Econometrics: A Modern Approach*, 7^{th} Edition. Cengage Learning India Pvt. Ltd, India.

24-810-0607 MOOC

Credits (H/W for L-T-P): 4 (0-2-0)

Semester VII

Semester Credit: 22 (Major: 20, Seminar/Open ended labs/Online course: 2); Cumulative Credit: 155								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0701	Mathematical Methods for Statistics	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0702	Probability Theory	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0703	Family of Distributions	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0704	Sampling Theory and Methods - II	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-07xx	Elective - III	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0708	Practical-I and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
Elective - III (Choose any one course)								
24-810-0705	Categorical Data Analysis	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0706	Population Dynamics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0707	Biostatistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100

24-810-0701 Mathematical Methods for Statistics

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Demonstrate an understanding of limits and continuity of various functions	Apply
2.	Evaluate the Riemann - Stieltjes integral and verify the conditions for the existence of the integrals.	Evaluate
3.	Distinguish between the concepts of sequence and series, and determine limits of sequences and convergence and approximate sums of series	Analyse
4.	Compute the partial and total derivatives and maxima and minima of multivariable function	Apply
5.	Solve systems of linear equations, diagonalize matrices and Characterize quadratic forms	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2				2	2		
CO2	1				2	2		
CO3	2				2	2		
CO4	2				2	2		
CO5	2				2	2		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Riemann - Stieltjes integral - definition, properties and important theorems, Eulers summation formula, integrators of bounded variation, sufficient conditions for existence of Riemann - Stieltjes integrals, mean value theorems of Riemann - Stieltjes integrals. (12 Hours)

Module 2:

Sequences and series of functions - pointwise and uniform convergence, properties and theorems; Multivariable calculus - limit and continuity, total derivative, directional derivatives, differentiation of composite functions, Taylor's Theorem for a multivariable function, inverse and implicit functions, optima of a multivariable function, method of Lagrange multipliers. (18 Hours)

Module 3:

Matrices - rank of a matrix, elementary transformations of a matrix and properties, inverse of a matrix by elementary transformations; Generalized inverse matrices - definition and existence; solving linear equations, Moore - Penrose inverse, symmetric matrices, properties of generalized inverse. (12 Hours)

Module 4:

Quadratic forms - classification and its characteristic properties, canonical forms, gram matrices; characteristic roots and characteristic vectors of a matrix, nature of characteristic roots of some special types of matrices, algebraic and geometric multiplicity of characteristic roots, Cayley - Hamilton theorem, orthogonal and unitary reductions of quadratic forms, spectral decomposition of a matrix, singular value decomposition. (18 Hours)

Text Books:

1. Searle, S. R. and Khuri, A. I. (2017). *Matrix Algebra Useful for Statistics*, 2^{nd} Edition. Wiley, USA.
2. Khuri, A.T. (1993). *Advanced Calculus with Applications in Statistics*, 1^{st} Edition. John Wiley & Sons, Inc., USA, Chapters - 3 and 7.
3. Apostol, T.M. (1996). *Mathematical Analysis*, 2^{nd} Edition. Narosa Publishing House, New Delhi, Chapters - 6, 7, 9.
4. Shanti Narayan (1991). *A Textbook of matrices*, S. Chand & Company, New Delhi, Chapters - 3, 6, 7, 10, 11.
5. Searle, S.R. (1971). Linear models, John Wiley & Sons, New York, Chapter - 1.

References:

1. Gupta, S.L. and Gupta, N.R. (2003) *Principles of Real Analysis*, 2^{nd} Edition. Pearson Education, New Delhi.
2. Widder, D.V. (2020) *Advanced Calculus*, 2^{nd} Edition. PHI Learning Pvt. Ltd., New Delhi.
3. Nanda, S. and Saxena, V.P. (2022) *Real Analysis*, 1^{st} Edition. Allied Publishers Pvt. Ltd., India.
4. Graybill, F.A. (2001) *Introduction to Matrices with Applications in Statistics*, 2^{nd} Edition. Cengage Learning.
5. Rao, C. R. (2001) *Linear Statistical Inference and its Applications*, 2^{nd} Edition. Wiley Series, United States, Chapter 1b, 1c.

24-810-0702 Probability Theory

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify sigma fields and compute limits of a sequence of random variables	Remember
2.	Describe properties of probability measure and distribution function	Remember
3.	Define expectation and moments	Understand
4.	Compute moment inequalities using expectations	Apply
5.	Concepts of independence and its use in multiplication properties, zero-one laws	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1				3	3		
CO2	2		2		3	3		
CO3	2		1		3	3		
CO4	2		3		3	3		
CO5	1		2		3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Classes of sets, fields, sigma fields, minimal sigma field, Borel sigma field, sequence of sets, lim sup and lim inf of a sequence of sets, measure, probability measure, properties of measure, Caratheodory extension theorem (statement only), Lebesgue and Lebesgue - Steiltjes measures. Measurable functions, random variables, sequence of random variables, distribution function and properties, decomposition of distribution function, distribution function of vector random variables, correspondence theorem (statement only). (15 Hours)

Module 2:

Integration of a measurable function with respect to a measure, monotone convergence theorem, Fatou's lemma, dominated convergence theorem. Expectation properties, inequalities and moments. Basic inequality, Jenseon's inequality, Cr-inequality. Moment generating function, Characteristic function , uniqueness theorem, inversion theorem, Bochner's theorem (statement only). (15 Hours)

Module 3:

Convergence in distribution, Convergence in probability, almost sure convergence, rth mean and interrelations, Levy's continuity theorem (statement only), Borel 0-1 law, Kolmogrov 0-1 law (statement only), Helly-Bray Lemma and theorem, independence. (15 Hours)

Module 4:

Kolmogrov's inequality, Weak law of large numbers – Bernoulli's, Khinchin's, Markov's. Kolmogorov's strong law of large numbers; Central limit theorem – De Moviers, Lindeberg-Levy, Liapnov's, Lindberg-Feller's theorems. (15 Hours)

Text Books:

1. Bhat, B.R. (2011). *Modern Probability Theory*, 2^{nd} Edition. Wiley Eastern, New Jersey, Chapters 1, 2, 3, 4, 5, 6, 9.

2. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Basu, A.K. (2012). *Measure Theory and Probability*, 2^{nd} Edition. PHI Learning Pvt. Ltd., New Delhi.

2. Billingsley, P. (2012) *Probability and Measure*, 3^{rd} Edition. Wiley Series, United States.

3. Bartle, R. G. (2010), *A Modern Theory of Integration*. American Mathematical Society, India.

4. Feller, W. (1991) *An Introduction to Probability Theory and Its Applications*, 3^{rd} Edition. Wiley India Pvt. Ltd, India.

5. Laha, R.G. and Rohatgi, V.K. (2020) *Probability theory*, Dover Publications Inc., New York.

6. Loeve, M. (1977) *Probability Theory*, 4^{th} Edition, Springer - Verlag, New York.

7. Rao, C. R. (2009). *Linear Statistical Inference and its Applications*, 2^{nd} Edition. John Wiley & Sons, New Delhi.

24-810-0703 Family of Distributions

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe and employ various statistical concepts to study the discrete distributions	Apply
2.	Describe and employ various statistical concepts to study the discrete distributions	Apply
3.	Describe properties of bivariate continuous exponential Distributions	Understand
4.	Illustrate characterization properties of the bivariate exponential	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2				3	3		
CO2	2		2		3	3		
CO3	2		3	3	3	3		2
CO4	3		2	3	3	3		3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Discrete Distributions: Modified power series family - properties, moment generating functions, recurrence relations for raw, central and factorial moments, recurrence relation for cumulants, binomial, negative binomial, logarithmic series and Lagrangian distributions as special cases of the results from modified power series family. (15 Hours)

Module 2:

Continuous distribution: Pearson family – identifications of the different types, beta, gamma, Pareto and normal as special cases of the Pearson family; exponential family of distributions, compound, truncated and mixture distributions - Lindley distribution; transformation of random variables. (15 Hours)

Module 3:

Sampling distributions: sampling distributions of the mean and variance from normal population, independence of mean and variance, chi - square, Student's - t and F distribution and their non - central forms, order statistics and their distributions, conditional distribution of order statistics, distribution of sample range. (15 Hours)

Module 4:

Bivariate distributions: multinominal, bivariate normal, bivariate exponential distribution of Gumbel, Marshall and Olkin and Block and Basu, Dirichlet distribution. (15 Hours)

Text Books:

1. Rohatgi, V.K. (1976). *An Introduction to Probability Theory and Mathematical Statistics*, John Wiley and Sons, New York.
2. Arnold, B.C., Balakrishnan, N. and Nagaraja, H.N. (2008). *A First Course in Order Statistics*. Society for Industrial and Applied Mathematics, United States of America.
3. Galambos, J. and Kotz, S. (2006). *Characterizations of Probability Distributions.: A Unified Approach with an Emphasis on Exponential and Related Models* (Vol. 675). Springer, Heidelberg.
4. Ord, J.K. (1972). *Families of Frequency Distributions*. Griffin's Statistical Monographs & Courses, London.

References:

1. Johnson, N. L., Kemp, A. W. and Kotz, S. (2005). *Univariate Discrete Distributions* (Volume 444), 3^{rd} Edition. John Wiley & Sons, New York.
2. Johnson, N. L., Kotz, S. and Balakrishnan, N. (1995). *Continuous Univariate Distributions* (Volume 2), 2^{nd} Edition. John Wiley & Sons, New York.

24-810-0704 Sampling Theory and Methods - II

Credits (H/W for L-T-P): 4 (2-1-2)

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Classify the notion of sampling under ratio and regression methods	Understand
2.	Compute sample estimators for the population parameters under ratio and regression methods	Apply
3.	Compute estimators for population parameters under PPSWR and PPSWOR	Apply
4.	Employ two - stage sampling with equal and unequal sizes and double sampling	Apply
5.	Compute estimators when errors, non - responses present and under adaptive sampling	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	2					
CO2	2			2				
CO3						2		
CO4		2		2		2		
CO5	3	2		2				
CO6	2				2			

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to SRS, stratified, systematic and cluster sampling; Ratio estimator - optimum property of ratio estimator, unbiased ratio type estimator; Difference estimator and regression estimator - difference estimator, regression estimator, comparison of regression estimator with mean per unit and ratio estimator, regression estimator in stratified random sampling. (20 Hours)

Module 2:

PPSWR - estimation of population mean and total, selection of a PPSWR sample; PPSWOR - properties of a sampling design, Horvitz - Thomson, Yates - Grundy, estimators; Midzuno - Sen - Lahiri, Des Raj, Murthy sampling strategies. (18 Hours)

Module 3:

Multistage sampling - subsampling with units of equal sizes, optimum sampling, three stage sampling, subsampling with units of unequal sizes; Multiphase sampling - double sampling for difference, ratio and regression estimations. (12 Hours)

Module 4:

Errors in surveys - effect of unit non - response in the estimate, procedures for unit non - response; quota sampling, network sampling; Adaptive sampling - introduction and estimators under adaptive sampling. (10 Hours)

Text Books:

1. Cochran, W. G. (2007). *Sampling Techniques*, 3rd Edition. Wiley India Pvt. Ltd, India.
2. Mukhopadhyay, P. (2008). *Theory and Methods of Survey Sampling*, 2nd Edition. PHI Learning Pvt Ltd, New Delhi.
3. Bansal, A. (2017). *Survey Sampling*, Narosa Publishing House Pvt Ltd, India.

References:

1. Arnab, R. (2017). *Survey Sampling Theory and Applications*, Academic Press.
2. Sampath, S. (2005). *Sampling Theory and Methods*, 2nd Edition. Alpha Science International Ltd, U. K.
3. Murthy, M.N. (1967). *Sampling Theory and Methods*, Statistical Publishing Society, Calcutta.
4. Singh, D. and Chaudhary, F.S. (2020). *Theory and Analysis of Sample Survey Designs*, 2nd Edition. New Age International Private Limited, New Delhi.

24-810-0708 Practical-I and Viva Voce

Credits (H/W for L-T-P): 2 (0-0-4)

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Apply the different mathematical methods using R software	Apply
2.	Apply the different sampling methods for designing and selecting a sample from a population	Apply
3.	Apply the methods of generating random numbers from different probability distributions and its goodness-of-fit using R software	Apply
4.	Formulate and solve problems which involve different probability distributions	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	3	3			3		3
CO2	2	2	3			3		3
CO3	2	1	2			3		3
CO4	2	2	1			3		3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Practicals based on topics covered in

- 24-810-0701 - Mathematical Methods for Statistics (15 Hours)
- 24-810-0703 - Family of Distributions (15 Hours)
- 24-810-0704 - Sampling Theory and Methods (15 Hours)
- 24-810-0705/06/07 - Elective Course (15 Hours)

Semester VIII

B.Sc (Honours) in Statistics

Semester Credit: 22 (Major: 20; seminar/open ended labs/online course: 2); Cumulative Credit: 177

Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0801	Theory of Estimation	STAT Major - DSC	24-810-0703	2-1-2	4	50	50	100
24-810-0802	Stochastic Processes	STAT Major - DSC	24-810-0702	2-1-2	4	50	50	100
24-810-0803	Advanced Techniques for Data Analysis	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0804	Mini Project	STAT Major - DSC	None	0-4-0	4	50	50[b]	100
24-810-08xx	Elective - IV	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0808	Practical-II and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
Elective - IV (Choose any one course)								
24-810-0805	Reliability Modelling and Analysis	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0806	Introduction to Information Theory	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0807	Statistical Analysis of Clinical Trials	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
Exit with B.Sc. (Honours) in Statistics (Total credits = 177)								

B.Sc (Honours with Research) in Statistics

24-810-0801	Theory of Estimation	STAT Major - DSC	24-810-0703	2-1-2	4	50	50	100
24-810-0802	Stochastic Processes	STAT Major - DSC	24-810-0702	2-1-2	4	50	50	100
24-810-0808	Practical-II and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
24-810-0809	Project	STAT Major - DSC	None	0-12-0	12	50	50[b]	100
Exit with B.Sc. (Honours with Research) in Statistics (Total credits = 177).								

24-810-0801 Theory of Estimation

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Verify the desirable properties of good estimators	Evaluate
2.	Relate complete sufficient statistic, Rao-Blackwell theorem and Lehmann-Scheffe theorem.	Analyse
3.	Relate Cramer-Rao, Chapmann-Robbin's and Bhattacharya bounds	Analyse
4.	Compute estimator of parameter or parameters of any given distribution using various methods	Apply
5.	Compare classical inference and Bayesian inference	Analyse
6.	Evaluate Bayes and minimax estimator of parameters of any given distribution	Evaluate
7.	Illustrate Metropolis-Hasting algorithm, Gibbs sampler and MCMC method	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	2	1		2	3	2
CO2	3	1	1			3	3	
CO3	3	1	1			3	3	
CO4	2	2				3		
CO5	3					3	3	
CO6	3	3	2			3	2	
CO7	2	2				3		3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Problem of point estimation: Unbiasedness - bias and MSE of an estimator; Consistency (weak, strong and squared error consistency) - marginal and joint consistent estimators, invariance property of consistent estimator, CAN estimator, BAN estimator; Sufficiency - likelihood equivalence, minimal sufficiency and completeness, factorization theorem; exponential family, Pitman family, ancillary statistic and Basu's Theorem, equivariance and Pitman estimators. (18 Hours)

Module 2:

Fisher information measure and its properties, Fisher information matrix, lower bound to the variance of an unbiased estimator, Cramer - Rao, Chapman - Robbin's and Bhattacharya bounds, UMVUE estimators and their characterizations, Rao - Blackwell theorem, Lehmann - Scheffe theorem, UMVUE estimation of parametric functions from standard distributions, BLUE of parametric functions, efficiency. (14 Hours)

Module 3:

Methods of estimation - methods of moments, method of maximum likelihood, method of minimum chi-square and modified minimum chi - square, method of least squares, properties of maximum likelihood estimators, Cramer - Huzurbazar theorem; Likelihood equation - multiple roots, iterative methods, E.M. algorithm. (15 Hours)

Module 4:

Basic elements of Bayesian inference, loss function, prior distribution, posterior distributions, Bayes risk, Bayes principle, Bayes estimators, minimax estimators, Bayes theorem, Metropolis - Hastings algorithm, Gibbs sampler, MCMC method. (13 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.
2. Rajagopalan, M. and Dhanavanthan, P. (2012). *Statistical Inference*. PHI Learning Private Limited, New Delhi.
3. Kale, B. K. (2005). *A First Course on Parametric Inference*, 2^{nd} Edition. Alpha Science International, India.

References:

1. Casella, G. and Berger, R. L. (2002). *Statistical Inference*, 2^{nd} Edition. Duxbury Advanced Series, USA.
2. Rao, C. R. (2009). *Linear Statistical Inference and its Applications*, 2^{nd} Edition. John Wiley & Sons, New Delhi.
3. Mukhopadhay, P. (2006). *Mathematical Statistics*, 3^{rd} Edition. Books and Allied Pvt. Ltd., Kolkata.
4. Robert C. P. and Casella, G. (2004). *Monte Carlo Statistical Methods*, 2^{nd} Edition. Springer, New York.
5. Lehmann, E. L. and Casella, G. (1998). *Theory of Point Estimation*, 2^{nd} Edition, Springer, New York.

24-810-0802 Stochastic Processes

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the classifications of random processes and concepts such as strict stationarity, wide-sense stationary and ergodicity	Understand
2.	Classify the states of a Markov chain and apply ergodic theorem for finding limiting distributions on states	Analyse
3.	Apply Poisson, birth-death, renewal processes and Brownian motion	Apply
4.	Describe and use the recurrence relation for generation sizes in a branching process and determine the probability of ultimate extinction	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	3			3	3	2	
CO2	2	2	2	1	3	3	1	
CO3		3			2	3	3	3
CO4	3	3			2	3	3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Stochastic process, stationary process, Markov process, martingales; Markov chains - definition, examples and classification, discrete renewal equation and basic limit theorem, absorption probabilities, criteria for recurrence. (25 Hours)

Module 2:

Continuous time Markov chains, examples, general pure birth process, Poisson process, birth and death process, finite state continuous time Markov chains, applications to queuing models. (15 Hours)

Module 3:

Galton-Watson branching processes, generating function, extinction probabilities, continuous time branching processes, extinction probabilities, branching processes with general variable life time. (10 Hours)

Module 4:

Renewal equation, renewal theorem, applications, generalizations and variations of renewal processes, applications of renewal theory, Brownian motion. (10 Hours)

Text Books:

1. Karlin, S. and Taylor, H. M. (1975). *A First Course in Stochastic Processes*, 2^{nd} Edition. Academic Press, United States. Relevant sections of Chapters 1, 2, 3, 4, 5 and 8.
2. Medhi, J. (2020). *Stochastic Processes*, 5^{th} Edition. New Age International Publishers, New Delhi.
3. Bhat, B. R. (2021). *Stochastic Models Analysis and Applications*, 2^{nd} Edition. New Age International, New Delhi.

References:

1. Cinlar, E. (1975). *Introduction to Stochastic Processes*. Dover Publications Inc., New York.
2. Ross, S. M. (1995). *Stochastic Processes*, 2^{nd} Edition. John Wiley & Sons, New Jersey.
3. Basu, A. K. (2003). *Introduction to Stochastic Process*, Alpha Science International Ltd., United Kingdom.
4. Kulkarni, V. G. (2011). *Introduction to Modeling and Analysis of Stochastic Systems*, 2^{nd} Edition, Springer, New York.

24-810-0803 Advanced Techniques for Data Analysis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand longitudinal data and its analysis	Understand
2.	Apply regression techniques for longitudinal data	Apply
3.	Employ various data resampling techniques	Analyse
4.	Understand the analysis of missing data and analyse various methods for the same	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2		2	1			
CO2		1			1			2
CO3		2			3	3		3
CO4	3	1		1		2		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction - longitudinal studies; Design considerations - bias, efficiency, sample size calculations; Exploring longitudinal data - graphical representation of longitudinal data, fitting smooth curves to longitudinal data, exploring correlation structure, general linear models for longitudinal data. (15 Hours)

Module 2:

Longitudinal regression - cohort vs longitudinal effect, robust estimation, weighted least-squares, robust standard error estimation; Parametric estimation - ML and REML; marginal, subject specific and transition models for continuous, binary and count outcomes, concept of GEE. (15 Hours)

Module 3:

Resampling techniques - permutation tests, introduction to jackknife and bootstrap methods for estimating bias, standard error and distribution function based on iid random variables, standard examples of bootstrap confidence intervals. (15 Hours)

Module 4:

Informative or non-informative missingness, MCAR, MAR and MNAR, complete case / available case estimation mean imputation, hot and cold deck imputation, MICE. EM & MCEM algorithms and data augmentation techniques. (15 Hours)

Text Books:

1. Diggle, P. J., Heagerty, P. J., Liang, K. Y. and Zeger, S. L. (2002). *Analysis of Longitudinal Data*, 2^{nd} Edition. Oxford University Press, London.
2. Efron, B. (1982). *The Jackknife, the Bootstrap, and Other Resampling Plans*. Society for Industrial and Applied Mathematics, Philadelphia.
3. Faraway, J. J. (2009). *Linear Models with R*. CRC, London.
4. Little, R. and Rubin, D. (2019). *Statistical Analysis with Missing Data*, 3^{rd} Edition. Wiley, New Jersey.

References:

1. Fitzmaurice, G., Laird, N. and Ware, J. *Applied Longitudinal Analysis*, 2^{nd} Edition. John Wiley & Sons, New Jersey.
2. Crowder, M. J. and Hand, D. J. (1990). *Analysis of Repeated Measures*, 1^{st} Edition. Chapman and Hall CRC Press, London.
3. Hand, D. and Crowder, M. (1996). *Practical Longitudinal Data Analysis*, 1^{st} Edition. Chapman and Hall CRC Press, London.
4. Lindsey, J. K. (1999). *Models for Repeated Measurements*, 2^{nd} Edition. Oxford University Press, London.
5. McCullagh, P. and Nelder, J. A. (1989). *Generalized Linear Models*, 2^{nd} Edition. Chapman and Hall CRC Press, London.
6. Weiss, R. E. (2005). *Modeling Longitudinal Data*, 1^{st} Edition. Springer, New York.
7. Enders C. K. (2022). *Applied Missing Data Analysis*, 2^{nd} Edition. Guilford Press, New York.
8. McLachlan G. J. and Krishnan T. (2007). *The EM Algorithm and Extensions*, 2^{nd} Edition, Wiley, New Jersey.
9. Efron B. and Tibshirani, R. J. (1994). *An Introduction to Bootstrap*, 1^{st} Edition. Chapman and Hall CRC Press, London.

24-810-0804 Mini Project

Credits (H/W for L-T-P): 4 (0-4-0)

24-810-0809 Project

Credits (H/W for L-T-P): 12 (0-12-0)

24-810-0808 Practical-II and Viva Voce

Credits (H/W for L-T-P): 2 (0-0-4)

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand various tools using a programming software	Understand
2.	Apply different statistical inference problems using real data sets and interpretation of the results	Analyse
3.	Formulate and solve problems which involve setting up stochastic models	Evaluate
4.	Apply topics related to the chosen Elective paper using real data sets and interpretation of the results	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2		3		3	3		3
CO2		3			3	3		3
CO3		3			3	3	2	3
CO4		3			3	3	2	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Practicals based on topics covered in

- 24-810-0801 - Theory of Estimation (15 Hours)
- 24-810-0803 - Advanced Techniques in Data Analysis (15 Hours)
- 24-810-0804 - Stochastic Processes (15 Hours)
- 24-810-0805/06/07 - Elective Course (15 Hours)

Semester IX

Semester Credit: 22-24 (Major: 20, Online Course: 2-4); Cumulative Credit: 199-201								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0901	Testing of Hypothesis	STAT Major - DSC	24-810-0801	2-1-2	4	50	50	100
24-810-0902	Multivariate Analysis	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	24-810-0302 (To choose as DSE)	2-1-2	4	50	50	100
24-810-0903	Applied Regression Analysis	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	24-810-0302 (To choose as DSE)	2-1-2	4	50	50	100
24-810-0904	Design and Analysis of Experiments-II	STAT Major - DSC	24-810-0801	2-1-2	4	50	50	100
24-810-09xx	Elective - XIII	STAT Major - DSE	24-810-0503	2-1-2	4	50	50	100
24-810-0908	MOOC (2-4 credits)[c]	STAT Major - DSE	None	0-2-0	2-4	-	100	100
Elective - V (Choose any one course)								
24-810-0905	Operations Research - II	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0906	Reliability Engineering	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0907	Applications of Integral Transforms	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100

24-810-0901 Testing of Hypothesis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1	Identify the given statistical testing problem	Evaluate
2	Evaluate MP and UMP tests corresponding to any given testing problem	Evaluate
3	Relate confidence interval estimation and testing of hypothesis	Analyse
4	Compute shortest confidence interval for parameter/s of any given distribution using different methods	Apply
5	Formulate LR test corresponding to any given testing problem	Evaluate
6	Construct SPRT corresponding to any given testing problem	Evaluate
7	Examine the non-parametric alternatives for each parametric tests	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	3	3		3	2	
CO2	2	2	1			3		
CO3	3	2		1	2	2		
CO4	2					2	3	3
CO5	2	1	2	3	2	3	2	
CO6	3	2			1	2		
CO7	2							

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Review of basic elements of testing of hypothesis, randomized and non- randomized tests, most powerful (MP) test, Neyman-Pearson lemma and its generalization, monotone likelihood ratio (MLR) property, uniformly most powerful (UMP) tests, unbiased and uniformly most powerful unbiased (UMPU) tests with examples, α-similar tests, tests with Neyman structure, locally most powerful (LMP) tests. (17 Hours)

Module 2:

Confidence interval estimation, relationship between confidence interval estimation and testing of hypothesis, UMA and UMAU confidence intervals, shortest confidence intervals, construction of confidence intervals using pivots, large sample confidence interval based on maximum likelihood estimator, central limit theorem and Chebyshev's inequality; Bayesian credible regions. (16 Hours)

Module 3:

Likelihood ratio tests and their properties, testing mean and variance of a normal population, testing equality of means and variances of two normal populations, sequential probability ratio test (SPRT), construction of SPRT with examples, properties of SPRT. (13 Hours)

Module 4:

Non-parametric inference: Goodness of fit tests - chi square test and Kolmogorov- Smirnov test for one and two sample problems, sign test, signed rank test, Wald-Wolfowitz run test, median test, Man-Whitney U-test, non-parametric confidence intervals, bootstrapping confidence intervals, P-P plot and Q-Q plot, Kendall's tau. (14 Hours)

Text Books:

1. Lehmann, E. L. and Romano, J. P. (2022). *Testing Statistical Hypothesis*, 4^{th} Edition. Springer, Switzerland.
2. Wald, A. (2013). *Sequential Analysis*. Dover Publications, New York.
3. Gibbons, J. D. and Chakraborti, S. (2021). *Nonparametric Statistical Inference*, 6^{th} Edition. CRC Press, London.
4. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Kale, B. K. (2005). *A First Course on Parametric Inference*, 2^{nd} Edition. Alpha Science International, India.
2. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.
3. Mukhopadhay, P. (2006). *Mathematical Statistics*, 3^{rd} Edition. Books and Allied Pvt. Ltd., Kolkata.
4. Casella, G. and Berger, R. L. (2002). *Statistical Inference*, 2^{nd} Edition. Duxbury Advanced Series, USA.
5. Dixit, U. J. (2016). *Examples in Parametric Inference with R*, 1^{st} Edition. Springer, Singapore.

24-810-0902 Multivariate Analysis

Credits (H/W for L-T-P): 4 (2-1-2)

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe random vectors and their properties	Understand
2	Discuss the multivariate normal distribution and its properties	Understand
3	Understand the concept of Wishart distribution, distributions of simple, partial and multiple correlations and T^2 and D^2 statistics.	Understand
4	Identify various classification methods for multivariate data and cluster analysis.	Analyse
5	Explain principal component analysis and factor analysis	Evaluate
6	Identify canonical variables and quantify canonical correlation	Analyze

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1	2	2				1	
CO2		2	2					
CO3		2	2					
CO4	2		2				2	
CO5	2		2				2	
CO6	2		2				2	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Multivariate data, preliminary analysis, notion of multivariate distributions, multivariate normal distribution, marginal and conditional distributions, characteristic function, estimation of mean vector and covariance matrix, Wishart distribution and its properties, distribution of simple, partial and multiple correlations based on samples from normal population. (15 hours)

Module 2:

Hotelling's T^2 and Mahalanobis D^2 statistics, properties of T^2 and D^2, multivariate Fisher-Behren's problem, testing independence of sets of variates, testing equality of covariance matrices and means, sphericity tests, testing the hypothesis that a covariance matrix equal to given matrix, mean and covariance equal to a given vector and given matrix. (15 hours)

Module 3:

Classification problem - standards of good classification, procedures of classification into one of two populations with known probability distributions, classification into one of two known multivariate normal populations, classification into one of several populations; Clustering of observations - hierarchical clustering for continuous and categorical data, different choices of proximity measures, agglomerative and divisive algorithms, K-means clustering optimum choice of the number of clusters. (18 hours)

Module 4:

Principal component analysis - definition, properties and ML estimation, canonical variables, canonical correlation; Factor analysis - the orthogonal factor model, estimation of factor loading, factor rotation, estimation of factor scores, interpretation of factor analysis, multidimensional scaling. (12 hours)

Text Books:

1. Anderson, T. W. (2003). *An Introduction to Multivariate Statistical Analysis*, 3^{rd} Edition. Wiley, India.

2. Johnson, R. A. and Wichern, D. W. (2015). *Applied Multivariate Statistical Analysis*, 6^{th} Edition. Pearson, India.

References:

1. Everitt, B. and Hothorn, T. (2011). *An Introduction to Applied Multivariate Analysis with R*, 1^{st} Edition. Springer, New York.

2. Rao, C. R. (2009). *Linear Statistical Inference and its Applications*, 2^{nd} Edition. John Wiley & Sons, New Delhi.

3. Rencher, A. C. and Christensen, W. F. (2012). *Methods of Multivariate Analysis*, 3^{rd} Edition. John Wiley & Sons, India.

24-810-0903 Applied Regression Analysis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify a linear and nonlinear regression problem	Apply
2.	Model a data using an appropriate regression model	Analyse
3.	Identify and interpret a regression model	Understand
4.	Examine model diagnostics	Analyse
5.	Identify a non parametric regression problem	Analyse
6	Apply non parametric regression techniques	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		2						
CO2		3	2					3
CO3		3						
CO4		2				2	3	3
CO5					3			
CO6					2	2		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Simple linear regression model, multiple linear regression model, least squares estimation, Gauss Markov theorem, properties of the estimates, distribution theory, maximum likelihood estimation; Hypothesis testing - likelihood ratio test, F-test; confidence intervals, Bonferroni-t-intervals, max modulus t intervals, Scheffes's method, estimation with linear restrictions, generalised least squares. (20 Hours)

Module 2:

Residual analysis, departures from underlying assumptions, effect of outliers, collinearity, non-constant variance and serial correlation, departures from normality, diagnostics and remedies. (10 Hours)

Module 3:

Polynomial regression in one and several variables, orthogonal polynomials, indicator variables, subset selection of explanatory variables, stepwise regression and Mallows, C_p- statistics, introduction to non-parametric regression. (15 Hours)

Module 4:

Introduction to nonlinear regression, least squares in the nonlinear case and estimation of parameters, models for binary response variables, estimation and diagnosis methods for logistic and Poisson regressions, prediction and residual analysis; Generalized linear models – estimation and diagnostics. (15 Hours)

Text Books:

1. Montgomery, D.C., Peck, E.A. and Vining, G.G. (2001). *Introduction to Regression Analysis*, 3^{rd} Edition. Wiley. Chapter 2, 3.

2. Seber, A. F. and Lee, A.J. (2003). *Linear Regression Analysis*, John Wiley, Relevant sections from chapters 3, 4, 5.

References:

1. Searle, S. R. (1997). *Linear Models*. John Wiley & Sons, New Jersey.

2. Draper, N. R. and Smith, H. (1998). *Applied Regression Analysis*, 3^{rd} Edition. John Wiley & Sons, New Jersey.

3. Fox, J. (1984). *Linear Statistical Models and Related Methods*, John Wiley, Chapter 5.

4. Christensen, R. (2001). *Advanced Linear Modeling*, Chapter 7, Springer, Switzerland.

5. Abraham, B. and Ledolter, J. (2009). *Statistical Methods for Forecasting*. Wiley, New Jersey.

24-810-0904 Design and Analysis of Experiments-II

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify one-way and two-way classifications	Understand
2.	Analyze one-way, two-way classifications, experiments with covariance and model adequacy checking procedures	Analyse
3.	Distinguish different types of basic designs of experiments	Understand
4.	Apply methods of analysing different types of basic designs of experiments	Apply
5.	Discuss factorial experiments and incomplete block designs	Understand
6.	Apply methods of analyzing factorial experiments and incomplete block designs	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2					
CO2	3		2	2				
CO3	3		2					
CO4	2		2			2		
CO5	2			3				
CO6				3				

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Randomization, replication and local control, one-way and two-way classifications with equal and unequal number of observations per cell with and without interaction, fixed and random effects models, model adequacy checking, CRD, RBD and Latin Square designs, orthogonal Latin squares, analysis of co-variance for CRD and RBD. (20 Hours)

Module 2:

Incomplete block designs - BIBD, properties, analysis with recovery of inter-block information and intra-block information, Youden square design, lattice designs, PBIBD, construction of PBIBD, analysis of PBIBD. (15 Hours)

Module 3:

2^n factorial experiments, 3^n factorial experiments, total and partial confounding of treatments in designs, fractional factorial designs, nested designs, asymmetrical factorial designs, split plot and strip plot designs. (18 Hours)

Module 4:

Response surface designs - orthogonality, rotatability blocking and analysis, method of steepest accent, models, properties and analysis. (7 Hours)

Text Books:

1. Montgomery, D. C. (2019). *Design and Analysis of Experiments*, 10^{th} Edition. John Wiley & Sons, New Jersey.

References:

1. Hinkelman, K. and Kempthrone, O. (2007). *Design and Analysis of Experiments, Volume-I*, 2^{nd} Edition. Wiley, United Kingdom.
2. Das, M. N. and Giri, N. C. (2017). *Design and Analysis of Experiments*, 3^{rd} Edition. New Age International Publishers, New Delhi.
3. Joshy, D. D. (1987). *Linear Estimation and Design of Experiments*. New Age International, New Delhi.

24-810-0908 MOOC

Credits (H/W for L-T-P): 2-4 (0-2-0)

Semester X

Semester Credit: 22-24 (Major: 20, Online Course: 2-4); Cumulative Credit: 221								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-1001	Time Series Analysis	STAT Major - DSC	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1002	Project Work	STAT Major - DSC	None	0-12-0	12	50	50[b]	100
24-810-10xx	Elective - VI	STAT Major - DSE	24-810-0503	2-1-2	4	50	50	100
24-810-1007	MOOC (2-4 credits)[c]	STAT Major - DSE	None	0-2-0	2-4	-	100	100
Elective - VI (Choose any one course)								
24-810-1003	Lifetime Data Analysis	STAT Major - DSE	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1004	Spatial Statistics	STAT Major - DSE	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1005	Advanced Bayesian Computing	STAT Major - DSE	None	2-1-2	4	50	50	100
24-810-1006	Statistics for Clinical Research	STAT Major - DSE	None	2-1-2	4	50	50	100

24-810-1001 Time Series Analysis

Credits (H/W for L-T-P): 4 (2-1-2)

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Assess the stationarity of time series and its decomposition	Evaluate
2.	Identify suitable models for the stationary component of the given time series	Analyse
3.	Analyse Spectral density and periodogram	Analyse
4.	Analyse time series in a state space set up	Analyse
5.	Compute Smooth and filter by Kalman algorithm	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	1			3		1
CO2	3	2				2		1
CO3			2			3		
CO4			1			3		
CO5			2			2		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Characteristics of time series - time series as a discrete parameter stochastic process, autocorrelation function (ACF) and cross-correlations, stationary time series, estimation of autocorrelations; classical regression in time series context, exploratory data analysis, smoothing methods for time series, Wold representation of linear stationary processes. (15 Hours)

Module 2:

Linear time series models - autoregressive (AR), moving average (MA), autoregressive moving average (ARMA) and autoregressive integrated moving average (ARIMA) models, forecasting and estimation of ARMA models, seasonal ARIMA models, residual analysis and diagnostic checking. (20 Hours)

Module 3:

Spectral analysis - time series in frequency domain, spectral density, periodogram and discrete Fourier transforms, estimation of spectral density, multiple series and cross spectra, linear filters. (12 Hours)

Module 4:

State space models - filtering, smoothing and forecasting using state space models, Kalman smoother, maximum likelihood estimation, missing data modifications. (13 Hours)

Text Books:

1. Shumway, R. H. and Stoffer, D. S. (2017). *Time Series Analysis and Its Applications*, 4^{th} Edition. Springer, Switzerland.

2. Box, G. E. P., Jenkins, G. M., Reinsel, G. C. and Ljung G. M. (2015). *Time Series Analysis: Forecasting and Control*, 5^{th} Edition. Wiley, New Jersey.

3. Brockwell, P. J. and Davis R. A. (1991). *Time Series: Theory and Methods*, 2^{nd} Edition. Springer, New York.

References:

1. Chatfield, C. (2003). *The Analysis of Time Series - An Introduction*, 6^{th} Edition. Chapman and Hall, New York.

2. Abraham, B. and Ledolter, J. (2009). *Statistical Methods for Forecasting*. Wiley, New Jersey.

3. Anderson, T. W. (2011). *The Statistical Analysis of Time Series*, 1^{st} Edition. Wiley, India.

4. Fuller, W. A. (1995). *Introduction to Statistical Time Series*, 2^{nd} Edition. Wiley, United Kingdom.

5. Kendall, M. G. (1990). *Time Series*, 3^{rd} Edition. Oxford University Press, Oxford.

6. Tanaka, K. (2017). *Time Series Analysis: Nonstationary and Noninvertible Distribution Theory*, 2^{nd} Edition. Wiley, New Jersey.

24-810-1002 Project Work

Credits (H/W for L-T-P): 12 (0-12-0)

24-810-1007 MOOC

Credits (H/W for L-T-P) : 2-4 (0-2-0)

List of Electives for VII/VIII/IX/X Semesters

24-810-0705 Categorical Data Analysis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Analyse categorical variables and multi-way tables	Analyse
2.	Understand different probability models and GLM and familiarise with the real life applications	Understand
3.	Calculate odds ratios and relative risks and associated inference procedures	Analyse
4.	Evaluate association rules of different orders	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1		2		1	2	2	
CO2	3	1	2		3			
CO3	2	1						2
CO4		2		2	2	2		3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to categorical data - categorical data, discrete distributions and related inference problems, statistical inference with categorical data, classes of models for discrete data; Analysis of two-way tables - analyzing 2×2 tables, analyzing $I \times J$ tables, test of independence for ordinal variables, graphs for two-way tables. Analysis of multi-way tables - describing multi-way contingency tables, on partial and marginal tables, analysis of K 2×2 tables, types of independence for three-way tables, graphs for multi-way contingency tables. (15 Hours)

Module 2:

Log-linear models - log-linear models for two-way tables, on inference and fit of log-linear models, log-linear models for three-way contingency tables, hierarchical log-linear models for multi-way tables, maximum likelihood estimation for log-linear models, model fit and selection, graphical models, collapsibility in multi-way tables. (15 Hours)

Module 3:

Generalized linear models and extensions - the generalized linear model (GLM), log-linear model - member of the GEM Family, inference for GLMs, software for GLMs, independence for incomplete tables, models for joint and marginal distributions. (15 Hours)

Module 4:

Association models - basic association models for two-way tables, maximum likelihood estimation for association models, association model selection, features of association models, association models of higher order - the RC(M) model, software applications for association models, association models for multi-way tables. (15 Hours)

Text Books:

1. Kateri, M. (2014). *Contingency Table Analysis: Methods and Implementation Using R*, 1^{st} Edition. Springer, New York.

2. Agresti, A. (2013). *Categorical Data Analysis*, 3^{rd} Edition, Wiley, New Jersey.

References:

1. Powers D.A. (1999). *Statistical methods for Categorical data analysis.* . Academic press Inc. New York.

24-810-0706 Population Dynamics

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the fundamental ideas, objectives and applications of population dynamics	Understand
2.	Employ life table functions and estimate the survival probability by method of MLE	Apply
3.	Understand the fundamental ideas about Leslie matrix techniques	Understand
4.	Apply population projection techniques by using a mathematical models	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2		1		2		3	
CO2		2			3		2	
CO3	2	1			3		2	
CO4	1	3	1		2		2	1

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Sources of mortality data, mortality measures, ratios and proportions, crude mortality rates, specific rates, standardization of mortality rates, direct and indirect methods, gradation of mortality data, fitting Gompertz and Makeham curves. (10 Hours)

Module 2:

Life tables, complete life table, relation between life table functions, abridged life table relation between abridged life table functions, construction of life tables, Greville's formula, Reed and Merrell's formula, sampling distribution of life table functions, multivariate pgf, estimation of survival probability by method of MLE. (15 Hours)

Module 3:

Fertility models; Fertility indices - relation between CBR, GFR, TFR, and NRR stochastic models on fertility and human reproductive process; Dandekar's modified binomial and Poisson models, Brass, Singh models for waiting time distributions, Sheps and Perrin model. (15 Hours)

Module 4:

Population growth indices, logistic model, fitting logistic, other growth models, Lotka's stable population, analysis, quasi stable population, effect of declining mortality and fertility on age structure, population projections, component method-Leslie matrix technique, properties of time independent Leslie matrix-models under random environment. (20 Hours)

Text Books:

1. Biswas, S. (1988). *Stochastic Process in Demography and Applications*. John Wiley & Sons, New Jersey.
2. Biswas, S. (2012). *Applied Stochastic Processes: A Biostatistical and Population Oriented Approach*, 2^{nd} Edition. New Central Book Agency (P) Limited, India.
3. Pollard, J. H. (1979). *Mathematical Models for the Growth of Human Populations*. Cambridge University Press, United Kingdom.

References:

1. Keyfitz, N. (1977) *Applied Mathematical Demography*, 2^{nd} Edition. Springer, New York.
2. Ramakumar, R. (2018). *Technical Demography*. New Age International, New Delhi.
3. Srinivasan, K. (1998). *Basic Demographic Techniques and Applications*, 1^{st} Edition. SAGE Publications, India.

24-810-0707 Biostatistics

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Discuss types of biological data and principles of bio statistical design of medical studies	Understand
2.	Explain the concepts of survival time functions of important parametric models and compare two survival distributions using LR test and Cox's F-test	Analyse
3.	Explain censoring and estimation of parameters using censored data	Understand
4.	Describe competing risk theory and estimate the probabilities of death by ML method	Analyse
5.	Discuss the basic biological concepts in genetics and clinical trials	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3					2	2	2
CO2	2	2	3					
CO3	2	1				2	2	1
CO4			1			2	3	2
CO5	3		2			3	2	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Biostatistics - example on statistical problems in biomedical research, types of biological data, principles of biostatistical design of medical studies; functions of survival time, survival distributions and their applications viz. exponential, gamma, Weibull, Rayleigh, lognormal, distribution having bath-tub shape hazard function, parametric methods for comparing two survival distributions (L.R test and Cox's F- test). (15 Hours)

Module 2:

Type I, Type II and progressive or random censoring with biological examples, estimation of mean survival time and variance of the estimator for type I and type II censored data with numerical examples, non-parametric methods for estimating survival function and variance of the estimator viz. acturial and Kaplan Meier methods. (15 Hours)

Module 3:

Categorical data analysis (logistic regression) - competing risk theory, indices for measurement of probability of death under competing risks and their inter-relations; estimation of probabilities of death under competing risks by ML method; Stochastic epidemic models - simple and general epidemic models. (15 Hours)

Module 4:

Basic biological concepts in genetics, Mendel's law, Hardy-Weinberg equilibrium, random mating, natural selection, mutation, genetic drift, detection and estimation of linkage in heredity, planning and design of clinical trials, phase I, II, and III trials, sample size determination in fixed sample designs, planning of sequential, randomized clinical trials, designs for comparative trials, randomization techniques and associated distribution theory and permutation tests (basic ideas only), ethics behind randomized studies involving human subjects, randomized dose-response studies (concept only). (15 Hours)

Text Books:

1. Biswas, S. (2012). *Applied Stochastic Processes: A Biostatistical and Population Oriented Approach*, 2^{nd} Edition. New Central Book Agency (P) Limited, India.

References:

1. Cox, D. R. and Oakes, D. (1984). *Analysis of Survival Data*, 1^{st} Edition. Chapman & Hall, London.

2. Elandt, R. C. and Johnson. (1971). *Probability Models and Statistical Methods in Genetics*. John Wiley & Sons, New York.

24-810-0805 Reliability Modelling and Analysis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand and discover the system reliability using the concept of structure functions	Understand
2.	Identify the various aspects like monotonic failure rates , bath tub and upside down bathtub shaped failure rates and other related measures for various life time	Evaluate
3.	Understand the various concepts and different notions of ageing used in reliability analysis and their inter relations	Understand
4.	Evaluate the concepts like positive dependency and various measures of dependence via - RCSI, LCSD, WPQD and their inter relations	Evaluate
5.	Estimate the reliability function for complete and censored samples through the maximum likelihood estimation and UMVU estimation and Bayesian method	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3				2	3		
CO2	3		2		2	3	2	
CO3			2		1	3	1	
CO4	1		1	2	2	3	1	
CO5	2		2		2	3	1	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Basic concepts in reliability, series and parallel systems, k out of n systems and its reliability, coherent systems, reliability of coherent systems, cuts and paths, bounds on system reliability. (15 Hours)

Module 2:

Life distributions, reliability function, hazard rate and mean residual life function, one to one correspondence of these functions, study of life time models viz, exponential, Weibull, Lognormal, Pareto, gamma, Makeham, Rayleigh distributions, proportional hazard models and their characteristics. (15 Hours)

Module 3:

Notions of ageing, increasing failure rate (IFR), increasing failure rate average (IFRA), new better than used (NBU), decreasing mean residual life (DMRL) and new better than used in expectation (NBUE), classes and their duals, loss of memory property of the exponential distribution, closures of these classes under formation of coherent systems, convolutions and mixtures. (15 Hours)

Module 4:

Reliability estimation using MLE - exponential, Weibull and gamma distributions based on censored and non-censored samples, Kaplan-Meier estimates of the distribution function, stress-strength reliability and its estimation. (15 Hours)

Text Books:

1. Barlow, R. E. and Proschan, F. (1987). *Mathematical Theory of Reliability*. Society for Industrial & Applied Mathematics, Philadelphia.
2. Sinha, S. K. (1986). *Reliability and Life Testing*. Wiley, New Jersey.
3. Lai, C. D. and Xie, M. (2006). *Stochastic Ageing and Dependence for Reliability*, 1^{st} Edition. Springer, New York.

References:

1. Barlow, R. E. and Proschan, F. (1985). *Statistical Theory of Reliability and Life Testing*. Holt, Rinehart and Winston, New York.
2. Rao, S. S. (1992). *Reliability-Based Design*, McGraw-Hill, New York.

24-810-0806 Introduction to Information Theory

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe measures of additive entropy and its properties	Understand
2.	Illustrate conditional entropy relative entropy and mutual Information	Analyze
3.	Describe Renyi entropy, conditional Renyi entropy	Understand
4.	Discuss non-additive entropy and its properties	Understand
5.	Describe maximum entropy principle	Evaluate
6.	Compute various inequalities in information theory	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2					1	
CO2	3	2					2	
CO3	2	2					2	
CO4	2	2				2		
CO5	2	2			2	2		
CO6		2	2				2	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Measures of additive entropy - statistical preliminaries, the Shannon entropy, Fadeev characterization, Tverberg characterization, Lee Characterization, properties of Shannon entropy, entropy rate, conditional entropy and information, chain rules for entropy, relative entropy and mutual information, Jensen's inequality and its consequences, the log sum inequality and its applications, the Renyi entropy and its characterizations, conditional Renyi entropy. (18 Hours)

Module 2:

Measures of non-additive entropy - polynomial entropy and their characterizations, non-polynomial algebraic entropy and characterizations, transcendental entropy and characterizations, Tsallis entropy - definition and properties. (12 Hours)

Module 3:

Maximum entropy distributions, examples, entropy based parameter estimation, entropy as a criterion for goodness of fit, dependence of entropy on sample size, comparison of other parameter estimation methods with entropy method. (12 Hours)

Module 4:

Inequalities in information theory - basic inequalities of information theory, differential entropy, bounds on entropy and relative entropy, inequalities for types, entropy rates of subsets, entropy and Fisher information, the entropy power inequality and the Brunn Minkowski inequality, inequalities for determinants, inequalities for ratios of determinants. (18 Hours)

Text Books:

1. Behara, M. (1991). *Additive and Non-additive Measures of Entropy*, 2^{nd} Edition. Wiley-Blackwell, New Jersey.

2. Cover, T. M. and Thomas, J. A. (2006). *Elements of Information Theory*, 2^{nd} Edition. Wiley-Interscience, New Jersey.

References:

1. Kapur, J. N. (2006). *Maximum-Entropy Models in Science and Engineering*, New Age International Publishers, India.

2. Gray, R. M. (2011). *Entropy and Information Theory*, 2^{nd} Edition. Springer-Verlag New York Inc., New York.

3. Tsallis, C. (2023) *Introduction to Non-extensive Statistical Mechanics: Approaching a Complex World*, 2^{nd} Edition. Springer Nature Switzerland AG, India.

4. Singh, V. P. (1998). *Entropy-Based Parameter Estimation in Hydrology*. Springer, India.

24-810-0807 Statistical Analysis of Clinical Trials

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the process of clinical trials and its importance	Understand
2.	Analyse various methods for designing clinical trials	Analyse
3.	Analyse the bio-equivalence for more than two drugs	Analyse
4.	Evaluate designs based on clinical end points	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2		1	3		1	
CO2		1	2	2	2		1	2
CO3		1	1		3		3	
CO4		3	2		2			3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to clinical trials - need and ethics of clinical trials, bias and random error in clinical studies, conduct of clinical trials, overview of phase I-IV trials, multi-center trials; Data management - data definitions, case report forms, database design, data collection systems for good clinical practice; bioavailability, pharma cokinetics and pharmacodynamics, two-compartment model. (15 Hours)

Module 2:

Design of clinical trials - parallel vs. cross-over designs, cross-sectional vs. longitudinal designs, objectives and endpoints of clinical trials, design of phase I trials, design of single-stage and multi-stage phase II trials, design and monitoring of phase III trials with sequential stopping, design of bio-equivalence trials; Inference for 2x2 crossover design - classical methods of interval hypothesis testing for bio equivalence, Bayesian methods, non-parametric methods. (20 Hours)

Module 3:

Power and sample size determination, multiplicative (or log-transformed) model, ML method of estimation, assessment of inter and intra subject variabilities, detection of outlying subjects; Optimal crossover designs - Balaams design, two-sequence dual design; optimal four period designs, assessment of bio-equivalence for more than two drugs, Williams design. (15 Hours)

Module 4:

Designs based on clinical endpoints - weighted least squares method, log-linear models, generalized estimating equations; drug interaction study, dose proportionality study, steady state analysis, interim analysis and group sequential tests, alpha spending functions, analysis of categorical data. (10 Hours)

Text Books:

1. Chow, S.C. and Liu, J.P. (2023). *Design and Analysis of Bioavailability and bioequivalence*, 3^{rd} Edition. CRC Press, New York.
2. Chow, S.C. and Liu, J.P. (2014). *Design and Analysis of Clinical Trials: Concepts and Methodologies*, 3^{rd} Edition. Wiley Series in Probability and Statistics.
3. Fleiss, J. L.(1999). *Design and Analysis of Clinical Experiments*, 1^{st} Edition. Wiley-Interscience, United Kingdom.

References:

1. Friedman, L. M., Furberg, C. D., DeMets, D. L., Reboussin, D. M., and Granger, C. B. (2015). *Fundamentals of Clinical Trials*, 5^{th} Edition. Springer, New York.
2. Jennison, C. and Turnbull, B. W. (1999). *Group Sequential Methods with Applications to Clinical Trials*, 1^{st} Edition. Chapman and Hall/CRC Press, India.
3. Marubeni, E. and Valsecchi, M. G. (2004). *Analyzing Survival Data from Clinical Trials and Observational Studies*, 1^{st} Edition. Wiley-Interscience, United States.

24-810-0905 Operations Research - II

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Examine the properties of linear programming problem	Understand
2.	Solve different types of LPP	Analyse
3.	Solve LPP using duality	Apply
4.	Employ transportation and assignment problems	Apply
5.	Solve non-linear programming problems	Apply
6.	Examine deterministic and probabilistic inventory models	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3			2				
CO2	3							
CO3	3			2				
CO4	3							
CO5	2			2				
CO6	2							

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Linear programming - convex sets and associated theorems, graphical method, definition of linear programming problem, properties of a solution to the linear programming problem, generating extreme-point solutions, simplex computational procedure, artificial variables technique - big M method, two phase method, revised simplex method. (20 Hours)

Module 2:

Duality problems of linear programming - unsymmetric primal-dual problems, symmetric primal-dual problems; Degeneracy and anticycling procedures - perturbation techniques; Transportation problems - general transportation problem, finding initial basic feasible solution, test for optimality, degeneracy in transportation problem, unbalanced transportation problem, maximization transportation problem; Assignment problem - mathematical formulation of the problem, the assignment method (Hungarian method). (18 Hours)

Module 3:

Non-linear programming problem (NLPP) - general non-linear programming problem; Constrained optimization with equality constraints - necessary conditions for a generalized NLPP, sufficient conditions for a general NLPP with one constraint, sufficient conditions for a general problem with $m(< n)$ constraints; Constrained optimization with inequality constraints - Kuhn Tucker conditions for general NLPP with $m(< n)$ constraints; quadratic programming problem, convex programming problems. (12 Hours)

Module 4:

Inventory models : Deterministic inventory models - general inventory model, static economic order quantity (EOQ) models - classic EOQ model, EOQ with price breaks, multi-item EOQ with storage limitation; Probabilistic inventory models - continuous review models - probabilitized EOQ model, probabilistic EOQ model, single-period models - no setup model (Newsvendor model), setup model ($s - S$ policy). (10 Hours)

Text Books:

1. Gass, S.I. (2011). *Linear Programming: Methods and Applications*, 5^{th} Edition. Dover Publications Inc., India.
2. Swarup, K., Gupta, P. K., and Mohan, M. (2022). *Operations Research*, 20^{th} Edition. Sultan Chand & Sons, India.
3. Taha H.A. (2019). *Operations Research - An introduction*, 10^{th} Edition. Pearson Education, India.

References:

1. Ravindran, A., Philips, D.T. and Soleberg, J.J. (2007). *Operation Research: Principles and Practice*, 2^{nd} Edition. John Wiley & Sons, India.
2. Paneerselvam, R. (2023). *Operations Research*, 3^{rd} Edition. PHI Learning, New Delhi.

24-810-0906 Reliability Engineering

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Compute reliability and hazard functions in modelling lifetime data and systems	Apply
2.	Calculate stress-strength based reliability	Analyze
3.	Differentiate maintainability and availability	Analyze
4.	Distinguish different types of failure modes	Understand
5.	Employ reliability tests and analysis of reliability plots	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2			2		
CO2	3		2			2		
CO3	2		2					
CO4			2					
CO5	2		2			3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Definition of reliability, pattern of failures, factor of safety and reliability, reliability and hazard functions, modelling of failure rates, estimation of failure rates from empirical data, parallel and series systems, (k/n) systems, complex systems, reliability enhancement, reliability allocation. (15 Hours)

Module 2:

Strength based reliability and inference theory - general expression for reliability, expression for probability of failure, reliability when strength and load follow normal, log-normal, exponential and extreme value distribution; Structural Reliability - one member-one load case, single member-several load case, reliability analysis of parallel system. (15 Hours)

Module 3:

Maintainability and availability - maintainability, preventive maintenance, imperfect maintenance, repair time distributions; Availability – availability analysis development of the model; systems with a single component, series and parallel systems, system safety analysis, failure models and effects - analysis, event - tree analysis, failure tree analysis, minimal cut-sets. (15 Hours)

Module 4:

Objectives of reliability test, analysis of failure time, accelerated life testing, censoring and acceleration, sequential life testing, statistical inference and parameter estimation, confidence intervals, plotting of reliability data, Bayesian analysis. (15 Hours)

Text Books:

1. Rao, S.S. (1992). *Reliability - Based Design*, McGraw-Hill, New York.

2. Breneman, J. E., Sahay, C., and Lewis, E. E. (2022). *Introduction to Reliability Engineering*, 3rd Edition. John Wiley and Sons, India.

References:

1. Tobis, P.A. and Trindade, D.C. (2012). *Applied Reliability*, 3rd Edition. CRC Press, London.

2. Rausand, M. and Hoyland, A. (2021). *System Reliability Theory – Models, Statistical Methods, and Applications*, 3rd Edition. Wiley-Blackwell, New Jersey.

3. Villemeur, A. (1992). *Reliability, Availability, Maintainability and Safety Assessment* (Volume 2), John Wiley and Sons, New York.

4. Pages, A., Gondran, M., and Griffin, E. (1986). *System Reliability: Evaluation & Prediction in Engineering*, Springer-Verlag, New York.

24-810-0907 Applications of Integral Transforms

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the basic concepts of integral transforms	Understand
2.	Apply Laplace transform, Fourier transform, Hankel transform and Mellin transform	Apply
3.	Evaluate Hilbert transform, Stieltjes transform, Z-transform	Analyse
4.	Apply Hilbert transform, Stieltjes transform, Z-transform	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		3			3	3		
CO2	3			3	3	3		
CO3	3			3	3	3		
CO4	3				3	3	3	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Basic concepts of integral transforms; Fourier transforms - introduction, basic properties, applications to solutions of ordinary differential equations (ODE), partial differential equations, applications of Fourier Transforms to solutions of ODEs, PDEs, and integral equations; evaluation of definite integrals, theorems, Watson's Lemma, solutions to ODE, PDE including initial value problems; Laplace transforms - introduction, existence criteria. (17 Hours)

Module 2:

Laplace (IVP) and boundary value problems (BVP) transforms - convolution, differentiation, integration, inverse transform, Tauberian; applications of joint Fourier-Laplace transform, definite integrals, summation; Hankel Transforms - introduction, properties and applications to PDE; Mellin transforms - introduction, properties, applications; Generalized Mellin transforms. (15 Hours)

Module 3:

Hilbert Transforms, Stieltjes Transform, Z - Transforms, Radon transform, fractional calculus and its application. (13 Hours)

Module 4:

Integral transforms in fractional equation; Wavelet transform - discussion on continuous and discrete, Haar, Shannon, and Daubechies wavelets. (15 Hours)

Text Books:

1. Davies, B. (2002). *Integral Transforms and Their Applications*, 3^{rd} Edition. Springer, New York.

References:

1. Debnath, L. and Bhatta, D. (2014). *Integral Transforms and Their Applications*, 3^{rd} Edition. CRC Press, India.
2. Sarthok Sircar, *Integral Transforms and Their Applications*, NPTEL lecture notes.

24-810-1003 Lifetime Data Analysis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the basic concepts and ideas of survival analysis	Understand
2.	Examine the properties and methods for standard survival time distributions	Analyse
3.	Estimate survival functions using parametric and non-parametric methods	Evaluate
4.	Apply and interpret semi-parametric and parametric regression models for survival data	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2			1	2	2	
CO2	2	2			1	2	2	
CO3	2	1	2		3	2	1	
CO4	1	1	1		3	2	1	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Basic quantities and models - survival function, hazard function, mean residual life function, common Parametric Models for survival Data; Censoring and truncation - right censoring, left or interval censoring, truncation, likelihood construction for censored and truncated data, counting processes. (15 Hours)

Module 2:

Nonparametric estimation of basic quantities for right-censored and left-censored data - estimators of the survival and cumulative hazard functions for right-censored data, pointwise confidence intervals for the survival function (without derivation), estimators of the survival function for left-truncated and right-censored data, estimation of the survival function for left-censored data, estimating the hazard function; Hypothesis Testing - one-sample tests, tests for two or more samples. (15 Hours)

Module 3:

Semi-parametric proportional hazards regression with fixed covariates - coding covariates, partial likelihoods for distinct-event time data, partial likelihoods when ties are present, model building using the proportional hazards model, estimation for the survival function; Regression diagnostics - Cox-Snell residuals for assessing the fit of a Cox Model, graphical checks of the proportional hazards assumption, deviance residuals. (15 Hours)

Module 4:

Inference for parametric regression models - exponential, Weibull and log logistics; Multiple modes of failure – basic characteristics and model specification, likelihood function formulation, nonparametric methods. (15 Hours)

Text Books:

1. Klein, J.P. and Moeschberger, M.L. (2003). *Survival Analysis - Techniques for Censored and Truncated Data*, 2^{nd} Edition. Springer, New York.
2. Lawless, J.F. (2002). *Statistical Models and Methods for Lifetime Data*, 2^{nd} Edition. Wiley-Interscience, United States. Relevant Sections of the Chapter 9.

References:

1. Kalbfleisch, J.D. and Prentice, R.L. (2002). *The Statistical Analysis of Failure Time Data*, 2^{nd} Edition. Wiley-Interscience, United States.
2. Hosmer Jr, D.W. and Lemeshow, S. (2008). *Applied Survival Analysis - Regression Modelling of Time to Event Data*, 2^{nd} Edition. Wiley-Interscience, United States.
3. Nelson, W. (2004). *Applied Life Data Analysis*, 1^{st} Edition. Wiley-Interscience, United Kingdom.
4. Miller, R.G. (1998). *Survival Analysis*, 2^{nd} Edition. Wiley-Interscience, United States.
5. Deshpande, J. V. and Purohit, S. G. (2016). *Lifetime Data: Statistical Models and Methods*, 2^{nd} Edition. World Scientific, Singapore.

24-810-1004 Spatial Statistics

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe different types of spatial data (geostatistical, areal, point process)	Understand
2.	Understand how spatial autocorrelation plays a role in statistical modeling	Understand
3.	Model geo-statistical data from real life situations	Analyse
4.	Analyse aerial unit data from real life situations	Analyse
5.	Model process data from real life situations	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		3	3	1	2	3	2	
CO2		3	3	1	3	3	1	
CO3	1	3	3	2	2	2	3	3
CO4	1	3	3	2	2	2	3	3
CO5	1	3	3	2	2	2	3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction, spatial stochastic process; Types of spatial data - geostatistical process, areal process, point process; Geo-statistical theory - mean, variance and covariance; autocorrelation function, stationarity, variograms. (10 Hours)

Module 2:

Geo-statistical modelling - Gaussian process, spatial autocorrelation, parameter estimation, maximum likelihood method, least square method, model adequacy, spatial residuals, spatial prediction. (20 Hours)

Module 3:

Areal unit modelling - estimation of spatial autocorrelation, conditional autoregressive (CAR) models, parameter estimation, Bayesian estimation. (15 Hours)

Module 4:

Point process data modelling - point process theory, Poisson process, model for complete spatial randomness, test for spatial randomness, parameter estimation; log-Gaussian Cox process. (15 Hours)

Text Books:

1. Lieshout van, M. N. M. (2019). *Theory of Spatial Statistics A Concise Introduction*, 1st Edition. CRC Press, India.

2. Gelfand, A.E., Diggle, P., Guttorp, P. and Fuentes, M. (2010). *Handbook of Spatial Statistics*, 1st Edition. CRC Press, United States.

3. Banerjee, S., Carlin, B.P. and Gelfand, A.E. (2014). *Hierarchical Modeling and Analysis for Spatial Data*, 2nd Edition. CRC Press, India.

References:

1. Peter, J. D. (2023). *Statistical Analysis of Spatial and Spatio-Temporal Point Patterns*, 3rd Edition. CRC Press, London.

2. Gaetan, C. and Guyon, X. (2009). *Spatial Statistics and Modeling*. Springer, New York.

3. Cressie, N. A. C. (2015). *Statistics for Spatial Data*, 2nd Edition. John Wiley & Sons, United States.

4. Waller, L.A. and Gotway, C.A. (2004). *Applied Spatial Statistics for Public Health Data*, 2nd Edition. John Wiley & Sons, United States.

5. Schabenberger, O. and Gotway, C. A. (2023). *Statistical Methods for Spatial Data Analysis*, 1st Edition. CRC Press, London.

24-810-1005 Advanced Bayesian Computing

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe various aspects of decision theory	Understand
2.	Construction of utility function in real life situations	Apply
3.	Differentiate the relevance of various loss functions	Analyse
4.	Evaluate the Bayesian estimators arena of statistical methodology	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2				3		
CO2	2	2	1			2		2
CO3		1	2			3		2
CO4		2		3	2			3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Statistical decision problem – decision rule and loss, randomized decision rule, decision principle, sufficient statistic and convexity, utility and loss functions, standard loss functions, vector valued loss functions. (14 Hours)

Module 2:

Prior information - subjective determination of prior density, non-informative priors, maximum entropy priors, location and scale invariant priors, Jeffrey's prior, ML-II approach to prior selection, conjugate priors, game theory, minimax theorem (without proof), statistical games, method of finding minimax estimators. (16 Hours)

Module 3:

Bayesian hypothesis testing, prior and posterior odds, Bayes factor, Lindley's procedure for test of significance, decision theoretic approach to testing problem, predictive inference-introduction, standard predictive distribution, Laplace rule of succession, prediction for exponential family of distribution, Bayes prediction with induced loss. (15 Hours)

Module 4:

Bayesian inference for the linear model, homoscedastic disturbances, heteroscedastic disturbances, predictive distribution, estimation, hypothesis testing, general linear model, empirical Bayes model, robustness. (15 Hours)

Text Books:

1. Berger, O. J. (1985). *Statistical Decision Theory and Bayesian Analysis*, 2^{nd} Edition. Springer Science & Business Media, New York.

References:

1. Ferguson, T. S. (1967). *Mathematical Statistics-A Decision Theoretic Approach*, 1^{st} Edition. Academic Press, New York.
2. Lehmann, E. L. and Casella, G. (1998). *Theory of Point Estimation*, 2^{nd} Edition. Springer, New York.
3. Parmigiani, G., Inoue, L. Y. T. and Lopes, H. F. (2009). *Decision Theory-Principles and Approaches*, 1^{st} Edition. John Wiley & Sons, United Kingdom.

24-810-1006 Statistics for Clinical Research

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Drug discovery and development	Understand
2.	SAS programming	Analyse
3.	CDISC SDTM implementation	Apply
4.	TLF report generation	Apply
5.	Advanced biostatistics using SAS	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		2		2				
CO2		2						3
CO3		2					2	
CO4		2						

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to clinical research, clinical research process, clinical data flow from start to end, types of studies and study designs, introduction to SAS, introduction to PDV, dataset processing and programming, SAS statements, combining datasets - set and merge, SAS functions, good programming practices (GPP), data manipulations, SAS procedures. (20 Hours)

Module 2:

SDTM package introduction and fundamentals, special purpose domains, general observation classes, trial design and relationship datasets, specification development. (15 Hours)

Module 3:

Dataset - ADSL, ADaM basic data structure - BDS, ADaM occurrence data structure – OCCDS, other types of ADaM data structures. (15 Hours)

Module 4:

Reporting procedure, shell overview, Tables, Listings, and Figures, sensitivity analysis and tipping point analysis, missing data, subgroups and covariate analysis, case study on CSR. (10 Hours)

References:

1. https://learn.sas.com/search/index.php?q=clinical
2. https://support.sas.com/en/documentation.html
3. https://www.cdisc.org/standards/foundational/sdtm
4. https://www.cdisc.org/standards/foundational/sdtmig/sdtmig-v3-2
5. https://www.cdisc.org/standards/foundational/adam
6. https://www.cdisc.org/standards/foundational/adam/adamig-v1-1