Central University of Punjab, Bathinda

M.Sc. STATISTICS

Batch: 2023-2025

Department of Mathematics and Statistics
School of Basic Sciences

M.Sc. (Statistics) Programme

Graduate Attributes:

- Students will be able to develop a broad understanding of recent Statistical theories, tools and techniques.
- Students will be able to apply different Statistical techniques in various fields.
- Students will be able to plan and carry out research in pure and applied Statistics independently.
- They will compete at regional/national/international level for research/jobs in the area of Statistics.

M.Sc. Statistics (Semester-I)

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
STA.507	Statistical Methods with Packages	Core	3	0	0	3
STA.508	Statistical Methods with Packages (Practical)	Skill Based	0	0	2	1
MAT.506	Real Analysis	Core	3	0	0	3
MAT.508	Linear Algebra	Core	3	0	0	3
STA.512	Probability and Distribution Theory	Core	3	0	0	3
STA.523	Sampling Theory	Core	3	0	0	3
STA.524	Sampling Theory (Practical)	Skill Based	0	0	2	1
MAT.568	Basics of LateX (Practical)	Skill Based	0	0	2	1
	Remedial Classes	-	0	2*	0	-
Total			15	0	6	**18**

*non-credit course

M.Sc. Statistics (Semester II)

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
STA.521	Statistical Inference	Core	3	0	0	3
STA.522	Statistical Inference (Practical)	Skill Based	0	0	2	1
STA.525	Stochastic Processes	Core	3	0	0	3
STA.555	Quality Control and Time Series	Core	3	0	0	3
STA.556	Quality Control and Time Series (Practical)	Skill Based	0	0	2	1
MAT.526	Complex Analysis	Compulsory Foundation	3	0	0	3
XYZ	Interdisciplinary (From Other Departments)	IDC	2	0	0	2
STA.530	Basics of Python Programming (Practical)	Skill Based	0	0	2	1
MAT.536	Basics of Mathematics Software	Skill Based	0	0	2	1
STA.580	Extreme Value Theory	Discipline Elective (Opt any one)	3	0	0	3
STA.560	Non-Parametric Inference					
STA.528	Actuarial Statistics	Discipline Elective (Opt any one)	3	0	0	3
STA.529	Statistical Methods for Insurance					
STA.574	Statistical Simulation					
	Remedial Classes	-	0	2*	0	-
Total			**20**	**0**	**8**	**24**

*non-credit course

Interdisciplinary courses offered by Faculty (For students of other Departments)

STA.510	Basic Statistics	IDC	2	0	0	2

M.Sc. Statistics (Semester III)

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
STA.511	Operations Research	Compulsory Foundation	4	0	0	4
STA.551	Multivariate Analysis	Core	3	0	0	3
STA.552	Multivariate Analysis (Practical)	Skill Based	0	0	2	1
STA.553	Design and Analysis of Experiment	Core	3	0	0	3
STA.554	Design and Analysis of Experiment (Practical)	Skill Based	0	0	2	1
STA.575	Econometrics	Discipline Elective (Opt any one)	3	0	0	3
STA.557	Stochastic Finance & Machine Learning in Insurance					
STA.563	Entrepreneurship Skills	Compulsory Foundation	2	0	0	2
STA.601	Dissertation Part-I	Skill Based	0	0	8	4
XXX	Value Added Course (From Other Departments)	VAC	2	0	0	2
	Remedial Classes	-	0	2*	0	-
Total			**17**	**0**	**12**	**23**

*non-credit course

Value added courses offered by Department of Mathematics and Statistics (For PG students of other Departments)

MAT.528	Linear Programming (VAC)	Value Based	2	0	0	2

MOOCs May be taken up 40% of the total credits (excluding dissertation credits). MOOC may be taken in lieu of any course but content of that course should match a minimum 70%. Mapping is to be done by the respective department and students may be informed accordingly.

M.Sc. Statistics (Semester IV)

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
STA.602	Dissertation Part- II	Skill Based	0	0	40	20

Students will have an option to carry out dissertation work in industry, national institutes or Universities in the top 100 NIRF ranking.

Group dissertation may be opted, with a group consisting of a maximum of four students. These students may work using a single approach or multidisciplinary approach. Research projects can be taken up in collaboration with industry or in a group from within the discipline or across the discipline.

Total Credits for the course: 85

Examination pattern and evaluation for Masters' students from 2023-24 session onwards

Formative Evaluation: Internal assessment shall be 25 marks using any two or more of the given methods: tests, open book examination, assignments, term paper, etc. The Mid-semester test shall be descriptive type of 25 marks including short answer and essay type. The number of questions and distribution of marks shall be decided by the teachers.

Summative Evaluation: The End semester examination (50 marks) with 70% descriptive type and 30% objective type shall be conducted at the end of the semester. The objective type shall include one-word/sentence answers, fill-in the blanks, MCQs', and matching. The descriptive type shall include short answer and essay type questions. The number of questions and distribution of marks shall be decided by the teachers. **Questions for exams and tests shall be designed to assess course learning outcomes along with focus on knowledge, understanding, application, analysis, synthesis, and evaluation.**

The evaluation for IDC, VAC and entrepreneurship, innovation and skill development courses shall include MST (50 marks) and ESE (50 marks). The pattern of examination for both MST and ESE shall be same as ESE described above for other courses.

Evaluation of dissertation proposal in the third semester shall include 50% weightage by supervisor and 50% by HoD and senior-most faculty of the department.

The evaluation of dissertation in the fourth semester shall include 50% weightage for continuous evaluation by the supervisor for regularity in work, mid-term evaluation, report of dissertation, presentation, and final viva-voce; 50% weightage based on average assessment scores by an external expert, HoD and senior-most faculty of the department. Distribution of marks is based on report of dissertation (30%), presentation (10%), and final viva-voce (10%). The-- external expert may attend final viva-voce through offline or online mode.

Examination pattern from 2022-23 session onwards

Core, Discipline Elective, and Compulsory Foundation Courses			IDC, VAC, and Entrepreneurship, Innovation and Skill Development Courses	
	Marks	Evaluation	Marks	Evaluation
Internal Assessment	25	Various methods	-	-
Mid-semester test (MST)	25	Descriptive	50	Descriptive (70%) Objective (30%)
End-semester exam (ESE)	50	Descriptive (70%) Objective (30%)	50	Descriptive (70%) Objective (30%)

Dissertation Proposal (Third Semester)			Dissertation (Fourth Semester)		
	Marks	Evaluation		Marks	Evaluation

Supervisor	50	Dissertation proposal and presentation	Supervisor	50	Continuous assessment (regularity in work, mid-term evaluation) dissertation report, presentation, final viva-voce
HoD and senior-most faculty of the department	50	Dissertation proposal and presentation	External expert, HoD and senior-most faculty of the department	50	Dissertation report (30), presentation (10), final viva-voce (10)

Marks for internship shall be given by the supervisor, HoD and senior-most faculty of the department.

Some Guidelines for Internal Assessment

1. The components/pattern of internal assessment/evaluation should be made clear to students during the semester.

2. The results of the internal assessment must be shown to the students.

3. The question papers and answers of internal assessment should be discussed in the class.

4. The internal assessment shall be transparent and student-friendly and free from personal bias or influence.

Semester I

Course Title: Statistical Methods with Packages Course

L	T	P	Credits
3	0	0	3

Code: STA. 507

Total Lectures: 45 Learning outcomes:

The students will be able to

CLO1: Learn the different methods of data presentation.

CLO2: Understand about the measures of central tendency.

CLO3: Explore the exact sampling distributions.

CLO4: Exercise the application of testing in real-life problems.

CLO5: Knowing the concept of chi-square goodness of fit.

Units/ Hours	Contents	Mapping with CLO
I 12 Hours	**Descriptive Statistics**: Meaning, need and importance of statistics. Attributes and variables. Measurement and measurement scales. Collection and tabulation of data. **Diagrammatic representation of frequency distribution**: histogram, frequency polygon, frequency curve, ogives, stem and leaf plot, pie chart. Measures of central tendency, dispersion (including box and whisker plot), skewness and kurtosis. Linear regression and correlation (Karl Pearson's and Spearman's) and residual plots. **Activity:** Students will construct various statistical plots using real data. Students will also explore the concepts of the measures of central tendency.	CLO1 CL02
II 12 Hours	Population, random sample, parameter, statistic and sampling distributions. Normal, Chi-square, t and F distributions and their relations. Sample mean and sample variance associated with a random sample from a normal distribution: their independence and distributions, concepts of standard errors. **Activity:** Students will do the exact sampling distribution.	CLO3

III 11 Hours	Statistical hypotheses, Type I and II errors, level of significance, test of significance, concept of p-value. Tests of significance for the parameters of normal distribution (one sample and two sample problems) and the relevant confidence intervals. **Activity:** Students will explore the testing of hypotheses in practical applications.	CLO4
IV 10 Hours	Chi-square test of goodness of fit and independence of attributes. Test of significance for correlation coefficient (one and two sampl e problem). Testing variance of normal distribution, testing of proportion (one and two sample problem), testing of correlation coefficient (one sample and two sample problem). **Activity:** Students will explore the concept of goodness of fit.	CLO5

Transaction mode: Lecture/Demonstration/Co Operative learning / programming/Practical/Group discussion/Team teaching/ Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. A. M. Goon, M. K. Gupta and B. Das gupta, *Fundamentals of Statistics*, Vol I and II, 2005.
2. R. V. Hogg, J. McKean and A. Craig, *Introduction to Mathematical Statistics*, 8th Edition, Pearson, 2021.
3. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences*, 11th Edition, Wiley & Sons, 2018.

Course Title: Statistical Methods with

Packages (Practical)
Course Code: STA.508
Total Hours: 30

L	T	P	Credits
0	0	2	1

Topics should include graphic representation of statistical data, descriptive statistics, correlation, linear regression model.

Learning Outcome: The students will be able

- Understand the basic techniques for graphical representation of data.
- Explain the concepts of dependence are bivariate data.
- Understand the basic packages used in statistical methodologies.

Laboratory Work: Programming exercises on statistical software tools like R.

1. To explore the various graphical representation of data .
2. To find the sample mean and sample variance from data.
3. To find the various descriptive statistics of a given data.
4. To demonstrate the various concept of dependence in a bivariate data.
5. To discuss the concept of correlation in a given data.
6. To fitting of simple linear regression models.
7. To fitting of multiple linear regression models.Data fitting for distribution.
8. To display Random number generation.
9. Testing of hypothesis

Transaction mode: Lecture/Demonstration/Co Operative learning / programming/Practical/Group discussion/Team teaching/ Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. A. M. Goon, M. K. Gupta and B. Dasgupta, *Fundamentals of Statistics*, Vol I and II, 2005.
2. R. V. Hogg, J. McKean and A. Craig, *Introduction to Mathematical Statistics*, 8th Edition, Pearson, 2021.
3. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences*, 11th Edition, Wiley & Sons, 2018.

Course Title: Real Analysis

Course Code: MAT.506

Course type: Core

Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes: The students will be able to

CLO1: Apply the knowledge of set theory and metric spaces with properties.
CLO2: Illustrate various properties of compact sets and connected sets.
CLO3: Explain concepts of convergent sequences and continuity in metric spaces.
CLO4: Apply the knowledge of Riemann Stieltjes Integrals.
CLO5: Discuss the problem of interchange of limit processes for sequences of functions and pointwise/Uniform convergence of sequence of functions.

Units/ Hours	Contents	Mapping with CLO

I 12 Hours	**Metric spaces:** Definition and examples, Open and closed sets, Compact sets, Elementary properties of compact sets, k-cells, Compactness of k-cells, Compact subsets of Euclidean space $\mathbb{R}^k$, Bolzano Weierstrass theorem, Heine Borel theorem, Perfect sets, Cantor set, Separated sets, Connected sets in a metric space, Connected subsets of real line. **Activity:** Students will solve some problems which will be based on concepts of compact sets and connected sets	CLO1 CL02
II 11 Hours	**Sequences in Metric spaces:** Convergent sequences, Subsequences, Cauchy sequences, Complete metric space with examples, Cantor's intersection theorem (Statement only), Category of a set and Baire's category theorem. Banach contraction principle. **Activity:** Students will solve some problems which will be based on application of sequences, category theorem and Banach contraction theorem.	CLO3
III 12 Hours	**Continuity:** Limits of functions (in Metric spaces), Continuous functions, Continuity and compactness, Continuity and connectedness, Discontinuities, Uniform continuity. **Riemann Stieltje's Integral:** Definition and existence of Riemann Stieltje's integral, Properties of integral. Integration and Differentiation. Fundamental Theorem of Calculus, 1st and 2nd Mean Value Theorems of Riemann Stieltje's integral. **Activity:** Students will do examples/exercises related to continuity and its characterizations. Students will explore how Riemann Stieltje's integral is a generalization of the Riemann integral.	CLO4

IV 10 Hours	**Sequences and series of functions:** Problem of interchange of limit processes for sequences of functions, Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. **Activity:** Students will explore how uniform convergence is related to integration and differentiation.	CLO5

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. T. M. Apostol, *Mathematical Analysis*, Addition –Wesley, USA, 1981.
2. R. G. Bartle, *The Elements of Real Analysis*, John Willey and Sons, New York, 1976.
3. A. Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, Narosa, Publishing House, New Delhi, 2014.
4. W. Rudin, *Principles of Mathematical Analysis,* 3rd Edition, McGraw Hill, Kogakusha, International student Edition, 1976.
5. E. C. Titchmarsh, *The Theory of functions,* Oxford University Press, Oxford, 2002.

Course Title: Linear Algebra

Course Code: MAT.508

L	T	P	Credits
3	0	0	3

Total Hours: 45

Learning outcomes:

The students will be able to

CLO1: Review the basic notions in linear algebra that are often used in mathematics and other sciences

CLO2: Define Vector spaces, Subspaces and related results.

CLO3: Define Linear transformations and characteristic polynomials with examples.

CLO4: Illustrate various properties of canonical forms.

CLO5: Study of inner product spaces.

CLO6: Explain concepts of the Gram-Schmidt orthogonalization process and its application in construction of orthonormal basis.

Unit/ Hours	Content	Mapping with CLO
I 11 Hours	**Linear Transformations:** Linear transformations, Algebra of linear transformations, Isomorphism, **Matrix representation:** Matrix representation of a linear transformation. Change of basis, Rank and nullity of a linear transformation.	**CLO1 CLO2**
II 11 Hours	Inner product spaces. Norms and distances, Orthonormal basis, Orthogonality, Schwarz inequality, The Gram-Schmidt orthogonalization process. Orthogonal and positive definite matrices.	**CLO5 CLO6**
III 12 Hours	Annihilating Polynomials: Characteristic polynomial and minimal polynomial of a linear transformation, Characteristic values and Characteristic vectors of a linear transformation, Cayley Hamilton theorem.	**CLO3**
IV 11 Hours	Diagonalizing matrices, Diagonalizing real symmetric matrices, Characteristic polynomials and minimal polynomials of block matrices, Canonical forms: Jordan canonical forms, rational canonical forms. Quotient spaces, Bilinear forms, Symmetric and skew- Symmetric bilinear forms, Sylvester's theorem, quadratic forms, Hermitian forms.	**CLO4**

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory,* Cengage Learning, 2004.
2. K. Hoffman and R. Kunze: *Linear Algebra,* 2nd Edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2004.
3. V. Bist and V. Sahai, *Linear Algebra,* Narosa, Delhi, 2002.
4. S Lang, Linear Algebra, Undergraduate texts in mathematics, Springer, 1989.

Course Title: Probability and Distribution Theory
Course Code: STA.512

L	T	P	Credits
3	0	0	3

Total Lectures: 45

Learning Outcomes: The students will be able to

CL01: Understand the concept of random experiments and probability space.

CL02: Explain random experiments, probability distributions.

CL03: Explore the concept of distribution and random variables.

CL04: Classify various probability distributions.

CL05: Make use of discrete and continuous distributions.

CL06: Establish the various inequalities.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 11 Hours	Random experiments, sample spaces (finite and infinite), events, algebra of events, three basic approaches to probability. Product sample spaces, conditional probability, Bayes' formula.	CLO1
	Learning Activities: Students will understand random experiments. They will also be able to solve problems related to product sample spaces and Bayes' Formula.	
II 11 Hours	Random variables (discrete and continuous). Bernoulli trials and Bernoulli random variables, distribution function and its properties. Mean and variance. Discrete Distributions: Bernoulli, binomial, Poisson, hyper-geometric, geometric, negative binomial, uniform. Continuous Distributions: Uniform, normal, exponential, gamma, Beta, Cauchy, Weibull, Pareto, Laplace and Lognormal.	CLO2 & CLO3
	Learning Activities: Students will understand probability distributions. They will also be able to make a differentiation between discrete and continuous distributions.	

III 11 Hours	Bivariate random variable, joint, marginal and conditional p.m.fs. and p.d.fs. Bivariate normal distributions. Moment generating and probability generating functions. Functions of random variables and their distributions using Jacobian of transformation and other tools.	CLO4
	Learning Activities: Students will understand bivariate distributions. They will also be able to make a differentiation between conditional p.m.fs and p.d.fs.	
IV 12 Hours	Markov's, Chebychev's, Holder's, Jensen's and Liapounov's inequalities. Convergence in probability and in distribution, Weak law of large numbers. Central limit problem; De-Moivre-Laplace and Lindberg-Levy forms of central limit theorem.	CLO5
	Learning Activities: Students will construct new inequalities. They will also be able to make a differentiation between various inequalities.	

Transaction mode:

Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching /Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. E. J. Dudewicz and S. N. Mishra, Modern Mathematical Statistics, Wiley International Student Edition, 1988.
2. I. Miller and M. Miller, Mathematical Statistics, 8th Edition, Oxford & IBH Pub., 2013.
3. P. L. Meyer, Introductory Probability and Statistical Applications, 2nd Edition, Oxford & Lbh, 2017.
4. S. M. Ross, Introduction to Probability Models, 11th Edition, 2014.
5. V. K. Rohtagi and A. K. M. E. Saleh, An Introduction to Probability Theory and Mathematical Statistics, 3rd Edition, Wiley Eastern, 2015.

Course Title: Sampling Theory

L	T	P	Credits
3	0	0	3

Course Code: STA.523

Course type: Core Total

Hours: 45

Learning outcomes: The students will be able to

CLO1: Explain various sampling techniques.
CLO2: Classify among SRSWOR, SRSWR, stratified, etc.
CLO3: Make use of Two-stage sampling and double sampling techniques.
CLO4: Understand PPS WR/WOR methods as well as Yates, Grundy and Desraj estimators
CLO5: Discuss Sampling and Non-sampling errors with special reference to non- response problems.

Units/ Hours	Contents	Mapping with CLO
I 11 Hours	Introduction to usual notations used in sampling. Basic finite population sampling techniques: SRSWOR, SRSWR, stratified, systematic and related results on estimation of population mean/ total. Relative precision of different sampling techniques. Allocation problem in stratified sampling. **Activity**: Students will solve problems related to different types of sampling techniques for estimation of population parameters.	CLO1 CL02
II 12 Hours	Ratio and regression estimators based on the SRSWOR method of sampling. Two-stage sampling with equal size of first stage units. Double sampling for ratio and regression methods of estimation. Cluster sampling - equal clusters. **Activity:** Students will solve problems related to ratio regression, Two stage sampling method and clustering	CLO3

III 12 Hours	PPS WR/WOR methods [cumulative total, Lahiri's schemes] and related estimators of a finite population mean : [Thompson-Horwitz, Yates and Grundy estimator, Desraj estimators for a general sample size and Murthy's estimator for a sample of size 2]. **Activity:** Students will solve problems related to the PPS method using different estimators.	CLO4
IV 10 Hours	Sampling and Non-sampling errors with special reference to non- response problems. National sample surveys office (NSSO) and role of various statistical organizations in national development. **Activity:** Students will get an understanding about different statistical organizations and their roles.	CLO5

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. A. Chaudhuri, *Essentials of Survey Sampling*, Prentice Hall of India, 2010.
2. A. Chaudhari and H. Stenger, *Survey Sampling Theory and Methods*, 2nd Edition, Chapman and Hall, 2005.
3. D. Raj and P. Chandak, *Sampling Theory*, Narosa, 1988.
4. D. Singh and F.S. Chaudhary, *Theory and Analysis Of Sample Survey Designs*, John Wiley & Sons, 1986.
5. P. Mukhopadyay, *Theory and Methods of Survey Sampling*, 2nd Edition, Prentice Hall of India, 2008.
6. P.V. Sukhatme and P.V. Sukhatme, *Sampling Theory of Surveys with Applications*, Asia Publishing House, New edition, 1970.
7. S. K. Thompson, *Sampling*, John Wiley and Sons, New York, 2002.
8. W. G. Cochran, *Sampling Techniques*, John Wiley & Sons, New York, 1977.

Course Title: Sampling Theory (Practical) Course Code: STA.524
Total Hours: 30

L	T	P	Credits
0	0	2	1

Learning Outcome:

The students will be able

- Explain various methods of sampling and estimation of population parameters.
- Understand the concept of efficiency of various sampling methods.

Laboratory Work: Programming exercises on statistical software tools like R.

1. To find an estimate of population's means for SRSWOR from observations.
2. To find an estimate of the population total for SRSWOR from observations.

3. To find an estimate of population's means for SRSWR from observations.
4. To find an estimate of the population total for SRSWR from observations.
5. To compare the efficiency of SRSWR and SRSWOR from observations.
6. To find an estimate of population mean for stratified sampling technique from observations.
7. To find an estimation of population total for stratified sampling technique from observations.
8. Relative precision of stratified and other sampling techniques.
9. Relative precision of systematic and other sampling techniques
10. Derive regression estimator based on SRSWOR.
11. Derive ratio estimator based on SRSWOR.
12. Derive values for Double sampling under ratio and regression methods of estimation.

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Course Title: Basics of LaTeX (Practical)

Code: MAT.568

Total Hours: 30

L	T	P	Credits
0	0	2	1

Learning outcomes: The students will be able to

1. Installation of the LaTeX software in Windows and Linux and understanding LaTeX compilation and LaTeX editors.
2. Basic syntax used in LaTeX.
3. Writing mathematical equations, Matrices, Tables, Inclusion of graphics into LaTeX file.
4. Page configurations**:** Title, Abstract, Keywords, Chapter, Sections and Subsections.
5. References and their citations.
6. Labeling of equations, Table of contents, List of figures.
7. Use of Packages**:** amsmath, amssymb, amsthm, amsfonts, graphic.
8. Use of document classes**:** Article, Report, Book, Beamer.
9. Applications of LaTeX in writing reports, books, research papers and thesis.

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1 D. F. Griffiths and D. J. Higham, *Learning LaTeX,* 2nd Edition, Philadelphia, Pennsylvania, SIAM, 1997.

2 L. Lamport. LATEX: A Document Preparation System, User's Guide and Reference Manual. 2nd Edition, Addison Wesley, New York, 1994.

3 M. Goossens, F. M. Michel, and S. Alexander, The LaTeX companion, 2nd Edition, Addison-Wesley, 1994.

Semester II

Course Title: Statistical Inference Course

L	T	P	Credits
3	0	0	3

Code: STA.521
Total Hours: 45
Learning outcomes: The students will be able to
CLO1: Learn different estimation techniques.
CLO2: Identify a good estimator.
CLO3: Learn the concept of MVUE and UMVUE.
CLO4: Establish various properties of likelihood estimators.
CLO5: Understand the concept of statistical inference under Bayesian framework.

Units/ Hours	Contents	Mapping with CLO
I 12 Hours	Statistic and its sampling distributions, Concept of mean squared errors. Basic concepts of point estimation: Unbiasedness, consistency and efficiency of estimators. Examples from some standard discrete and continuous distributions. Sufficiency and minimal sufficiency, Exponential family of distributions, Factorization criteria, Completeness. **Activity:** Students will explore the basic concept of parametric estimation. They will learn how to extract a good estimator among the huge class of estimators.	CLO1& CL02
II 12 Hours	Minimum and uniformly minimum variance unbiased estimation, Rao-Blackwell and Lehmann-Scheffe theorems. Ancillary statistic, Basu's theorem and its applications. Fisher information measure, Cramer-Rao inequality, Chapman-Robin inequality, Bhattacharya bounds. **Activity:** Students will learn the concept of Fisher information measure and will construct some important lower bounds for variance	CLO3

III 11 Hours	Methods of estimation: Method of moments, Maximum likelihood estimators, Properties of maximum likelihood estimators, Least square estimation, Minimum chi-square method. **Activity:** Students will explore various methods of parameter estimation and will establish its statistical properties. .	CLO4
IV 10 Hours	Introduction to Bayesian Statistics and its applications: Loss function, Prior distribution, Bayes' theorem, Posterior distribution, Bayes' risk, Bayes' principle, Bayesian estimation, Properties of Bayesian estimator. **Activity**: Students will learn basic concepts of Bayes' estimation.	CLO5

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. A. K. M. E. Saleh and V. K. Rohatgi, *An Introduction to Probability and Statistics*, 3rd Edition, Wiley, 2015.
2. B. K. Kale, *A First Course on Parametric Inference*, Narosa Publishing House, 2005.
3. C. R. Rao, *Linear Statistical Inference and its Applications*, 2nd Edition, Wiley, 2009.
4. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley International Student Edition, 1988.
5. E. L. Lehmann, *Theory of Point, Estimation*, Student Edition, John Wiley & Sons, 1986.
6. G. Casella and R. L. Berger, *Statistical Inference*, 2nd Edition, Duxbury Thomson Learning, 2021.

Course Title: Statistical Inference (Practical) Course

L	T	P	Credits
0	0	2	1

Code: STA.522
Total Hours: 30

Laboratory experiments will be set in context with the materials covered in theory classes of Statistical Inference-I.

Learning Outcome: The students will be able

- Understand the basic techniques used in parametric estimation.
- Explain the concepts of selection of a better estimator based on sample.
- Understand the basic packages used in inferential statistics.

Laboratory Work:

1. To find an estimate in normal population.
2. To demonstrate consistence using data.
3. To demonstrate methods of moments using data.
4. To calculate maximum likelihood estimation in single parametric model.
5. To obtain maximum likelihood estimation in multiparametric model.
6. To find an estimate of population mean for stratified sampling technique from observations.
7. To find least squares estimates in regression model.
8. To find Bayes estimates in desecrate data.

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning. **Suggested Readings:**

1. A. K. M. E. Saleh and V. K. Rohatgi, *An Introduction to Probability and Statistics*, 3rd Edition, Wiley, 2015.
2. B. K. Kale, *A First Course on Parametric Inference*, Narosa Publishing House, 2005.
3. C. R. Rao, *Linear Statistical Inference and its Applications*, 2nd Edition, Wiley, 2009.
4. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley International Student Edition, 1988.
5. E. L. Lehmann, *Theory of Point, Estimation*, Student Edition, John Wiley & Sons, 1986.
6. G. Casella and R. L. Berger, *Statistical Inference*, 2nd Edition, Duxbury Thomson Learning, 2021.

Course Title: Stochastic Processes Course

Code: STA.525

Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning Outcomes: The students will be able to

CLO1: Explain Stochastic Processes.

CL02: Classify among various forms of stochastic processes.

CL03: Make use of Chapman Kolmogorov equations.

CL04: Justify Simple Birth, Birth Death Processes.

CL05: Discuss Wiener Processes.

Units/Hours	Contents	Mapping with Course Learning Outcome

I 12 Hours	Introduction to Stochastic Processes. Classification of stochastic processes according to state space and time domain into discrete/continuous time, discrete/continuous state spaces, elementary problems, Random walk and Gambler's ruin problems, Counting process. Applications of stochastic processes. Stationarity of stochastic processes, Weakly stationary and strongly stationary processes.	CLO1 & CLO2
	Learning Activities: Students will classify among various forms of stochastic processes. They will solve real life problems using the properties of stochastic processes.	
II 13 Hours	Markov chains: Definition and examples of Markov Chain, Transition probability matrix, classification of states, communicating classes, recurrence: non-recurrence, Irreducibility, Stationary distribution and its interpretation. Chapman- Kolmogorov equations, n-step transition probability matrices and their limits, stationary distribution.	CLO3
	Learning Activities: Students will solve problems related to Markov chains and derive the stationarity of the distribution.	
III 10 Hours	Statistical Inference for Markov Chains: Estimation of transition probabilities. Discrete state space continuous time Markov Processes: Poisson process, Simple Birth Process, Simple Death Process, Simple Birth- Death process.	CLO4
	Learning Activities: Students will explore about the various forms of stochastic processes and estimate their transition probabilities.	
IV 10 Hours	Continuous State Continuous Time Markov Processes: Brownian motion process, Wiener Process and its properties.	CLO5
	Learning Activities: Students will solve problems related to continuous state and continuous time stochastic processes.	

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. B. R. Bhat, *Stochastic Models: Analysis and Applications*, New Age International India, 2000.
2. J. Medhi, *Stochastic Processes*, 3rd Ed ,Wiley Eastern Ltd., 2012.

3. N. T. Bailey, *The Elements of Stochastic Processes*, John Wiley & Sons, Inc., New York, 1965.
4. S. M. Ross, *Stochastic Processes,* Wiley Publications, 1996.
5. S. Karlin and H. M. Taylor, *A First Course in Stochastic Processes*, Vol. 1, Academic Press, 1975.

Course Title: Quality Control and Time Series Course

L	T	P	Credits
3	0	0	3

Code: STA.555

Total Hours: 45

Learning outcomes: The students will be able to

CLO1: Understand the concept of quality technology and assurance, productivity

CLO2: Explain $\bar{X}$ and R charts, analysis of pattern on control charts, control chart for attributes - np, p, c and u charts

CLO3: Explain CUSUM, Group control charts, O. C. curve and ARL of control charts.

CLO4: Discuss Dodge's continuous sampling inspection plans.

CLO5: Get in-depth understanding of Time Series models

Units/ Hours	Contents	Mapping with CLO
I 11 Hours	The meaning of quality, quality assurance, technology and productivity. Statistical methods for quality control and improvement. Chance and assignable causes of quality variation, general theory of control charts, control charts for variables: $\bar{X}$ and R charts, analysis of pattern on control charts, control chart for attributes- np, p, c and u charts. **Activity**: Students will understand about quality of the product. They will construct various charts to detect pattern in the production process.	CLO1 CL02
II 11 Hours	Multiple stream processes: Group control charts. Specification limits and tolerance limits, O.C and ARL of control charts, CUSUM charts. **Activity**: Students will explore various multiple stream processes and solve problems related to them.	CLO3

III 12 Hours	Review of sampling inspection techniques, single, double, multiple and sequential sampling plans and their properties, methods for estimating (n, c) using large sample techniques, Dodge's continuous sampling inspection plans. **Activity:** Students will use various sampling inspection techniques to make an inference about the acceptance or rejection of the lot of final product.	CLO4
IV 11 Hours	Time series as discrete parameter stochastic process. Auto covariance and auto correlation functions and their properties. Moving average (MA), Auto regressive (AR), ARMA and ARIMA models. Box-Jenkins models. Choice of AR and MA periods. Estimation of ARIMA model parameters, correlogram analysis. **Activity**: Students will understand various time series models and solve problems to understand their applications.	CLO5

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. D. C. Montgomery and L. A. Johnson, *Forecasting and Time Series Analysis*, Mc Graw Hill, New York, 1976.
2. D. C. Montgomery, *Introduction to Statistical Quality Control*, 8th Edition., John Wiley & Sons, 2019.
3. G. B. Wetherill, *Sampling Inspection and Quality Control*, Halsted Press, 1977.
4. P. J. Brockwell and A. Daris Richard, *Introduction to Time Series And Forecasting*, 2nd Edition. Springer-Verlag, New York, Inc. (Springer Texts in Statistics), 2002.
5. S. Biswas, *Statistics of Quality Control, Sampling Inspection and Reliability*, New Age International Publishers Eastern Ltd, 1996.

Course Title: Quality Control and Time Series (Practical)
Course Code: STA.556
Total Hours: 30

L	T	P	Credits
0	0	2	1

Learning outcomes:

The students will be able to

- Explain various charts and how to construct them.
- Understand the concept of multiple stream processes.
- Understand the concept of various time series models.

Laboratory Work: Experiments are from the topics of Quality Control and Time Series using SPSS/R.

1. Construct $\bar{X}$ and R charts.
2. Construct control chart for attributes- np.
3. Construct control chart for p.
4. Construct control chart for c.
5. Construct control chart for u.
6. Construct CUSUM charts.
7. understand application of single sampling plan.
8. understand application of double sampling plan.
9. compare multiple and sequential sampling plans.
10. understand methods for estimating (n, c) using large sample techniques.

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Course Title: Complex Analysis
Course Code: MAT.526

L	T	P	Credits
3	0	0	3

Total Lectures: 45

Learning outcomes:

The students will be able to

CLO1: Recall complex number systems and algebra of complex variables.

CLO2: Illustrate the concept of analytic function and discuss the necessary and sufficient conditions for a function to be analytic.

CLO3: Understand the notion of complex line integral and related results.

CLO4: Discuss Mobius transformations and their properties.

CLO5: Apply ideas of Complex analysis in allied areas.

Units/ Hours	Contents	Mapping with CLO
I 10 Hours	Functions of a complex variable, limit, continuity, uniform continuity, differentiability, analytic function, Cauchy-Riemann equations, harmonic functions and harmonic conjugate. **Activity:** Students will make use of Cauchy- Riemann equations to investigate the functions of complex variables which are analytic or not.	CLO1 CL02
II 12 Hours	Complex line integral, Cauchy's theorem, Cauchy-Goursat theorem, Cauchy's integral formula and its generalized form, Cauchy's inequality. Poisson's integral formula (Statement only), Morera's theorem. Liouville's theorem. Contour integral, power series, Taylor's and Laurent's series. **Activity:** Students will find the applications of important theorems like Cauchy's theorem and Cauchy's integral formula. They will also work on various examples of contour integrals.	CLO3
III 12 Hours	Singularities of analytic functions, Fundamental theorem of algebra, zeros of analytic function, poles, residues, residue theorem and its applications to contour integrals. Maximum modulus principle, Schwarz lemma. **Activity:** Students will do the examples related to singularities and poles of analytic functions. They will explore the concept of residues and its applications to solve contour integrals.	CLO4
IV 11 Hours	Meromorphic functions, the argument principle, Rouche's theorem, Mobius transformations and their properties, definition and examples of conformal mappings. **Activity:** Students will explore the concept of Mobius transformations and its applications in different fields.	CLO5

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. H.S. Kasana, *Complex Variables:Theory and Applications,* 2nd Edition, PHI Learning Pvt. Ltd, 2005.
2. R. V. Churchill & J. W. Brown, *Complex Variables and Applications*, 9th Edition, Tata McGraw-Hill, 2014.
3. S. Ponnusamy, *Foundations of Complex Analysis*, 2nd Edition, Narosa Publishing House, 2007.
4. Theodore W. Gamelin, *Complex Analysis*. UTM, Springer-Verlag 2001.
5. W. Tutschke and H.L. Vasudeva, *An Introduction to Complex Analysis, Classical and Modern Approaches*, 1st Edition,CRC Publications, 2004.
6. Rajendra Kumar Sharma, Sudesh Kumari Shah and Asha Gauri Shankar, *Complex Numbers and Theory of Equations*, Anthem Press, 2011.
7. Lars V. Ahlfors, An Introduction to the Theory of Analytic Function of one complex variable, 3rd Edition, Tata McGraw-Hill, 2006.
8. Dennis G. Zill & Patrick D. Shanahan, A First Course in Complex Analysis with Application, 3rd Edition, Jones and Bartlett, 2003.
9. W. Tutschke and H.L. Vasudeva, *An Introduction to Complex Analysis, Classical and Modern Approaches*, 1st Edition, CRC Publications, 2004.
10. Rajendra Kumar Sharma, Sudesh Kumari Shah and Asha Gauri Shankar, *Complex Numbers and Theory of Equations*, Anthem Press, 2011

Course Title: Basic Statistics (I D C)

Course Code: STA.510

Total Hours: 30

L	T	P	Credits
2	0		2

Learning outcomes:

The student will be able to

CLO1: Explain descriptive statistics, probability distributions.

CLO2: Classify measures of central tendency and dispersion.

CLO3: Make use of basic approaches to probability.

CLO4: Justify axiomatic approach to probability.

CLO5: Discuss application of discrete and continuous random variables.

Units/Hours	Contents	Mapping with Course Learning Outcome

I 07 Hours	Descriptive Statistics: Meaning, need and importance of statistics. Attributes and variables. Measurement and measurement scales. Collection and tabulation of data. Diagrammatic representation of frequency distribution: histogram, frequency polygon, frequency curve, ogives, stem and leaf plot, pie chart.	CLO1
	Learning Activities: Students will construct important statistical plots with the help of real data.	
II 08 Hours	Measures of central tendency, dispersion (including box and whisker plot), skewness and kurtosis. Data on two attributes, independence and association of attributes in 2x2 tables. Simple linear regression and correlation (Karl Pearson's and Spearman's) and residual plots.	CLO2 & CLO3
	Learning Activities: Students will understand measures of dispersion and skewness They will also be able to solve problems related to simple regression and correlation.	
III 07 Hours	Random experiments, sample spaces (finite and infinite), events, algebra of events, three basic approaches to probability, combinatorial problems, conditional probability, Bayes' formula.	CLO4
	Learning Activities: Students will explore the concept of random experiments and learn the use of probability in daily life.	
IV 08 Hours	Random variables (discrete and continuous). Distribution Function and its properties, mean and variance. Discrete Distributions: Bernoulli, Binomial, Poisson, geometric, Continuous distribution: Uniform, exponential, normal.	CLO4
	Learning Activites: Students will solve problems on discrete and continuous distributions and learn how to apply these models in practical applications.	

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. F. E. Croxton and D. J. Cowden, *Applied General Statistics*, 2nd Edition, Pitman, 1962.
2. P. G. Hoel, *Introduction to Mathematical Statistics*, 4th Edition, New York, John Wiley and Sons, 1971.
3. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences*, 11th Edition, Wiley & Sons, 2018.

Course Title: Basics of Python Programming (Practical)
Course Code: STA.530
Total Hours: 30

L	T	P	Credits
0	0	2	1

Learning Outcome.
The students will be able to

- Explain various mathematical operators
- Illustrate mathematical function in **Python**
- Discuss methods to handle dataset in **Python**

Laboratory Work. Program related to Python programming.

1. A brief introduction about Python and installation of anaconda.
2. Numerical computations including square root, trigonometric functions using math and cmath module.
3. Dealing with different data types such as list, tuple and dictionary.
4. If statements, for loop and While loops and simple programmes using these.
5. User-defined functions and modules.
6. Various uses of lists, tuples and dictionaries.
7. Use of Matplotlib to plot graphs in various formats.
8. Classes in Python.
9. Use of Numpy and Scipy for solving problems in linear algebra and calculus, differential equations.
10. Data handling using Pandas

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Reading

1. Kenneth A, Fundamentals of Python First programs 2nd edition - Lambert, Cengage, Learning India.
2. Amit Saha, Doing Math with Python -, No starch Press,
3. E. Balgurusamy, Problem solving and Python programming- Tata McGraw Hill.
4. Paul Zimmermann, Computational Mathematics with SageMath- .
5. Razvan A. Mezei, Introduction to Programming using SageMath-, Publisher Wiley, 2021

Course Title: Basics of Mathematics Software

Course Code: MAT.536

Total Hours: 30

L	T	P	Credits
0	0	2	1

To be performed using Computer with aid of MATLAB/MATHEMATICA/MAPLE or any other such software

1. Plotting the graphs of the functions,exp(ax+b), log(ax+b),1/ax+b,sin(ax+b) , cos (ax+b) and |ax+b|to illustrate the effect of a and b on the graph.
2. Plotting the graphs of the polynomial of degree 4 and 5.
3. Sketching parametric curves (E.g. Trochoid, cycloid, hypocycloid).
4. Obtaining the surface of the revolution of curves.
5. Tracing of conics in Cartesian coordinates/polar coordinates.
6. Sketching ellipsoid, hyperboloid of one and two sheets (using Cartesian coordinates).
7. Construction of matrices and arithmetic operations among the matrices.

Suggested Readings:

1. Peter I. Kattan, MATLAB for Beginners: A Gentle Approach, Publisher: Petra Books, 2008.
2. H.Anton, I.Bivensand S.Davis, Calculus,10th Ed., John Wiley and Sons (Asia) P.Ltd., Singapore, 2002.
3. Shanti Narayan, P. K. Mittal, Differential Calculus, S. Chand, 2014.
4. Shanti Narayan, P. K. Mittal, Integral Calculus, S. Chand, 2014.
5. James Stewart, Single Variable Calculus, Early Transcendentals, Cengage Learning, 2016.
6. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi,2005.

Course Title: Extreme Value Theory

Course Code: STA.580

Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning Outcomes:

The students will be able to

After completing this course, student is expected to learn the following:

CLO1: Understand the basic concepts of order statistics, joint, marginal and conditional probability distributions of order statistics.

CLO2: Learn about distribution-free confidence intervals for population quantile and distribution free tolerance intervals for population distributions.

CLO3: Construct the recurrence relations and identities for moments of order statistics.

CLO4: Enhanced with the concepts of distributions of order statistics for independently and not identically distributed variates and also for dependent variates.

Units/Hours	Contents	Mapping with Course Learning Outcome
Unit I **12 Hours**	Order Statistics: Distribution of first and last order statistics, Distribution of a single order statistic, Joint distribution of two consecutive order statistics, Distribution of Range, spacing between two order statistics, ratio of two order statistics. Illustrative examples considering different family of distributions.	CLO1
	Learning Activities: Students will explore various concepts of order statistics.	
Unit II **11 Hours**	Fluctuations of Maxima - Limit distribution of linearly normalized maxima, Weak convergence of maxima. Maximum Domains of attraction and Norming constants – The maximum domains of attractions of extreme value distributions. Von Mises' theorem. Fluctuations of univariate upper order statistics. The Generalized Extreme Value Distribution, The Generalized Pareto Distribution	CLO2
	Learning Activities: Students will check various results and theorems related to mode of convergence for order statistics	
Unit III **11 Hours**	Diagnostic procedure to identify maximum domains of attractions: Hill Plot, Probability Paper Plot, Zipf's plot, QQ Plot, Mean Excess Plot, Sum Plot. Illustration contains different classes of distributions. Test for identification of max domain of attractions: Hasofer and Wang's test, Segers and Teugels test, Ratio between Maximum to sum of excess.	CLO3
	Learning Activities: Students will solve problems related to various diagnostic techniques.	
Unit IV **11 Hours**	Analysis the Hydrology, Insurance, Finance, Geology, Environment, Meteorology, Seismic dataset by graphical diagnostic procedure and fitting of suitable extreme value distribution.	CLO4
	Learning Activities: Students will explore various applications of extreme value distributions in real applications.	

Suggested Readings:

1. Embrechts, P., Kluppelberg, C., &Mikosch, T. Modelling extremal events: For insurance and finance. Sringer, 2013.
2. Beirlant, J., Goegebeur, Y., Segers, J., &Teugels, J. L. Statistics of extremes: theory and applications. John Wiley & Sons, 2006.
3. Kotz, S., &Nadarajah, S. Extreme value distributions: theory and applications. World Scientific, 2000.
4. Castillo, E., Hadi, A. S., Balakrishnan, N., &Sarabia, J. M. Extreme value and related models with applications in engineering and science, Wiley, 2005.

Course Title: Non-parametric Inference

L	T	P	Credits
3	0	0	3

Course Code: STA.560
Total Hours: 45
Learning Outcomes:

The students will be able to
CLO1: Explain estimable parametric function.
CLO2: Apply the concept of empirical distribution function.
CLO3: Understand test for randomness.
CLO4: Discuss about Rank Statistics and its limiting distribution.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 11 Hours	Estimable parametric functions, kernel, symmetric kernel, one sample U-Statistic. Two sample U-Statistic, asymptotic distribution of U-Statistics, UMVUE property of U-Statistics. Probability Inverse Transformation method and its application. Empirical distribution function, confidence intervals based on order statistics for quantiles, tolerance regions.	CLO1
	Learning Activities: Students will understand the concepts of empirical distribution and U- Statistic.	

II 11 Hours	Tests for randomness: Tests based on the total number of runs and runs up and down. Rank-order statistics. One sample and paired-sample techniques: sign test and signed-rank test. Goodness of fit problem: Chi-square and Kolmogorov-Smirnov tests. Independence in bivariate sample: Kendall's and Spearman's rank correlation.	CLO2
	Learning Activities: Students will understand the various concepts non- parametric tests.	
III 11 Hours	The General Two sample Problem: Wald Wolfwitz run test and Kolmogorov–Smirnov two sample test. Linear Rank Statistics: Linear Rank Statistics and its limiting distribution, Rank test, MP and LMP rank tests.	CLO3
	Learning Activities: Students will understand the problems of rank test.	
IV 12 Hours	General two sample location and scale problem: Tests for two-sample location problem: Wilcoxon-Mann-Whitney, Terry- Hoeffding, Kruskal-Wallis, Jonckheere-Terpstra tests. Concepts of Jackknifing, method of Quenouille for reducing bias, Bootstrap methods.	CLO4
	Learning Activities: Students will understand the concepts of bootstrap.	

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. A. C. Davison and D. V. Hinkley, *Bootstrap Methods and their Applications*, Cambridge University Press, 1997.
2. J. D. Gibbons and S. Chakraborti, *Nonparametrics Statistical Inference*, 2nd Edition, Marcel Dekker, Inc, 2003.
3. L. Wasserman, *All of Nonparametric Statistics*, 1st Edition, Springer, 2005.
4. M. L. Puri and P. K. Sen, *Nonparametric Methods in Multivariate Analysis*, John Wiley and Sons, 1971.
5. R. H. Randles and D. A. Wolfe, *Introduction to the Theory of Nonparametric Statistics*, Wiley, 1979.
6. W. W. Daniel, *Applied Nonparametric Statistics*, 2nd Edition, Duxbury, 2000

Course Title: Actuarial Statistics

Course Code: STA.528

Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes: The students will be able to

CLO1: Discuss various forms of rate of interest and their applications.

CLO2: Understand the concept of interest rates.

CLO3: Explain the concept of future lifetime, survival and mortality.

CLO4: Get in-depth understanding of assurance and annuity contracts

Units/Hours	Contents	Mapping with Course Learning Outcome
I 10 Hours	Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor.	CLO1
	Learning Activities: Students will solve problems related to different types of interest and discounting factor.	
II 09 Hours	Life tables functions like $\boldsymbol{l_x}$, $\boldsymbol{d_x}$ and probability of survival and Probability of death and their select equivalents.	CLO2
	Learning Activities: Students will solve problems how to evaluate survival and death probability from life table	
III 10 Hours	Define the distribution and density function of continuous future lifetime and curtate future lifetime random variable. Define force of mortality, survival function and derive relationship between them.	CLO3
	Learning Activities: Students will explore the concept of future lifetime distribution, force of mortality and solve problems related to them.	
IV 16 Hours	Assurance and annuity contracts: definitions of benefits and premiums, various types of assurances and annuities, present value, formulae for mean and variance of various continuous and discrete payments.	CLO4
	Learning Activities: Students will learn about various types of assurance and annuity. Students will solve problems related how to derive mean and variance of these contracts.	

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1 D. S. Borowaik and A. F. Shapiro, *Financial and Actuarial Statistics: An Introduction*, Marcel Dekker Inc., New York-Basel, 2005.

2 N. L. Bowers, H. U. Gerber, J. C. Hickman, D. A. Jones and C. J. Nesbitt, *Actuarial Mathematics*, 2nd Edition, Society of Actuaries, USA,1997.

3 P. J. Boland, *Statistical and Probabilistic Methods in Actuarial Science*, Chapman and Hall/CRC, 2007.

4 S. A. Klugman, H. H. Panjer, G. E. Willmot and G. G. Venter, *Loss Models:From Data to Decisions*. 5th Edition, Wiley-Interscience, 2019.

5 S. D. Promislow, *Fundamentals of Actuarial Mathematics*, 2nd Edition, Wiley, 2011.

Course Title: Statistical Methods for Insurance

Course Code: STA.529

Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes:

The students will be able to

CLO1: Understand the concept of loss distributions.

CLO2: Explain Insurance contracts.

CLO3: Classify collective and individual risk models.

CLO4: Discuss ruin theory.

CLO5: Get in-depth understanding of Bayesian inference and credibility theory.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 11Hours	Review of Loss distributions: Classical loss distributions, heavy-tailed distributions, reinsurance and loss distributions. Reinsurance and effect of inflation.	CLO1
	Learning Activities: Students will learn about loss distribution used in insurance sector.	
II 12 Hours	Risk models for aggregate claims: Collective risk model and individual risk model, premiums and reserves for aggregate claims, reinsurance for aggregate claims.	CLO2 & CLO3
	Learning Activities: Students will learn various types of risk models and solve problems related to them.	

III 11 Hours	Ruin theory: Surplus process in discrete time and continuous time, probability of ruin in finite and infinite time, adjustment coefficient, Lundberg inequality, applications in reinsurance.	CLO4
	Learning Activities: Students will learn the concept of ruin theory and solve application part of ruin theory in insurance sector.	
IV 11 Hours	Introduction to Bayesian inference, Credibility Theory, Full credibility for claim frequency, claim severity and aggregate loss. Bayesian credibility, Empirical Bayes credibility.	CLO5
	Learning Activities: Students will learn about the concept of Bayesian inference and credibility theory and solve problems related to them.	

Suggested Readings:

1. D. C. M. Dickson, *Insurance Risk and Ruin*, Cambridge University Press, 2nd ed., Cambridge, 2016.
2. E. S. Harrington and R. Gregory, *Risk Management and Insurance*: 2nd ed., Tata McGraw Hill Publicating Company Ltd. New Delhi,1998.
3. J. Grandell, *Aspects of Risk Theory*, Springer-Verlag, New York, 1990.
4. N. L. Bowers, H. U. Gerber, J. C. Hickman, D. A. Jones, and C. J. Nesbitt, *Actuarial Mathematics*, Second Edition, The Society of Actuaries. Sahaumburg, Illinois, 1984.
5. P. J. Boland, *Statistical and Probabilistic Methods in Actuarial Science*. Chapman & Hall, London, 2007.
6. S. Ramasubramanian, *Lectures on Insurance Models*, Hindustan Book Agency Texts and Readings in Mathematics, 2009.
7. T. Mikosch, *Non-Life Insurance Mathematics- An Introduction with a Poisson Process*, Springer, Berlin, 2004.

Course Title: Statistical Simulation Course
Code: STA.574

L	T	P	Credits
3	0	0	3

Total Hours: 45 Learning Outcomes:

The students will be able to

CLO1: Explain deterministic and stochastic processes.

CLO2: Apply the concept of random number generation.

CLO3: Understand Monte Carlo integration.

CLO4: Discuss about variance reduction techniques.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 11 Hours	Simulation: An introduction, need of simulation, physical versus digital simulation, Buffon's needle problem. Deterministic and stochastic processes. Use of simulation in defense and inventory problems. **Activity:** Students will understand the concepts of deterministic and stochastic processes	CLO1
II 11 Hours	Random Number Generation**:** Congruential generators, statistical tests for pseudo random numbers. **Activity:** Students will learn about random number generation.	CLO2
III 12 Hours	Random Variate Generation: Inverse transforms method, composition method, acceptance rejection method. Generating random variates from continuous and discrete distributions. Generation of random vectors from multivariate normal distribution. **Activity:** Students will learn about random sample generation some well known family of distributions.	CLO3
IV 11 Hours	Monte Carlo integration and variance reduction techniques : Hit or miss Monte Carlo method, sample mean Monte Carlo method, Jacknife Method. **Activity:** Students will understand the concept of Monte Carlo method.	CLO4

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching /Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. G. Gordon, *System Simulation*, Prentice Hall of India, New Delhi, 2001.
2. P. A. W. Lewis and E. J. Orav, *Simulation Methodology for Statisticians*, Operations Analysis and Engineering, Wadsworth & Brooks Cole Advanced Books & Software. Volume I, 1988.
3. R. Y. Rubinstein and D. P. Kroese, *Simulation and the Monte Carlo Method*, John Wiley & Sons, 2016.
4. T. T. Julius and R. C. Gonzalesz, *Pattern Recognition Principles*, Addison – Wesley PublishingCompany,1997.

Semester III

Course Title: Operations Research

L	T	P	Credits
4	0	0	4

Course Code: STA.511

Total Hours: 60

Learning outcomes:

The students will be able to

CLO1: Discuss the concept of convex sets and linear programming problems with formulation.
CLO2: Apply different methods to solve linear programming problems.
CLO3: explore the concept of Duality theory and Sensitivity analysis.
CLO4: Explain transportation problems and assignment problems with their mathematical formulation.
CLO5: Apply methods to test the optimality of transportation problems.
CLO6: Develop understanding of Sequencing problems, Games and strategies.

Units/ Hours	Contents	Mapping with CLO
I 15 Hours	Mathematical formulation of linear programming problem, Linear Programming and examples, Convex Sets, Hyper plane, Open and Closed half-spaces, Feasible, Basic Feasible and Optimal Solutions, Extreme Point & graphical methods. Simplex method, Big-M method, Two phase method, Determination of Optimal solutions, Unrestricted variables. **Activity:** Students will formulate linear programming problems and find solutions with graphical methods.	CLO1 CLO2
II 15 Hours	Duality theory, Dual linear Programming Problems, Fundamental properties of dual problems, Complementary slackness, Unbounded solution in Primal. Dual Simplex Algorithm. Sensitivity analysis: Discrete changes in the cost vector, requirement vector and coefficient matrix. **Activity:** Students will do problems to find solutions through Simplex method, Big-M method and two phase method. They will exercise dual linear programming problems.	CLO3

III 15 Hours	The General transportation problem, Duality in transportation problem, Loops in transportation tables, Solution of transportation problem, Test for optimality, Degeneracy, Transportation algorithm (MODI method), Minimization transportation problem. Assignment Problems: Mathematical formulation of assignment problem, Hungarian method for solving assignment problems, Traveling salesman problem. **Activity:** Students will do exercises on Sensitivity analysis and transportation problems.	CLO4 CLO5
IV 15 Hours	Sequencing Problem: General assumptions and basic terms used in sequencing. Processing n jobs through 2 machines, Processing n jobs through 3 machines. Games and Strategies: Two person zero sum games, Maximin - Minimax principle, Saddle points, Graphic and arithmetic solutions. **Activity:** Students will do exercises on Assignment problem and sequencing problem	CLO6

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 1987.
2. H. A. Taha, *Operations Research - An Introduction*, Macmillan Publishing Company Inc., New York, 2006.
3. K. Swarup, P. K. Gupta, and M. Mohan, *Operations Research*, Sultan Chand & Sons, New Delhi, 2001.
4. N. S. Kambo, *Mathematical Programming Techniques*, Affiliated East- West Press Pvt. Ltd., 1984, Revised Edition, New Delhi, 2005.
5. S. M. Sinha, *Mathematical Programming, Theory and Methods,* Delhi: Elsevier, 2006.

Course Title: Multivariate Analysis
Course Code: STA.551
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning Outcomes:

The students will be able to

CLO1: Learn various important properties of multivariate normal distribution.

CLO2: Analyze multivariate data.

CLO3: Understand multivariate hypothesis tests and infer appropriate conclusions.

CLO4: Use the Wishart distribution in real applications.

CLO5: Explore the principles of data reduction technique

Units/ Hours	Contents	Mapping with CLO
I 11 Hours	Multivariate normal distribution: Definition, conditional & marginal distributions, characteristic function. Maximum likelihood estimators of parameters. Distributions of sample mean vector and variance-covariance matrix and their independence. Null distribution of partial and multiple correlation coefficients. Application in testing and interval estimation. **Activity:** Students will explore the concept of multivariate normal distribution and will obtain its MLEs. Students will also apply multivariate normal population in testing and interval estimation.	CLO1 & CL02
II 11 Hours	Hotelling's T^2 , its distribution and applications. One sample, two sample and application in tests on mean equality of the components of a mean vector in a multivariate normal population. Mahalanobis D^2 and its sampling distribution. **Activity:** Students will learn the generalization of Student's t- distribution and will use it in one sample and two sample problems.	CLO3
III 11 Hours	Wishart distribution and its properties. Distribution of sample generalized variance. Classification and discriminant procedure for discriminating between two multivariate normal populations, Sample discriminant function and related tests. Probabilities of misclassification and their estimation. **Activity:** Students will learn about classification and discriminant procedure for discriminating between two multivariate normal populations.	CLO4

IV 11 Hours	Generalized variance, Wilk's criterion and Multivariate Analysis of Variance [MANOVA] of one-way classified data. Testing independence of sets of variates and equality of covariance matrices. Principle components, dimension reduction, canonical variables and canonical correlation: definition, use, estimation and computation. **Activity:** Students will explore the concept of data reduction and also learn about canonical correlation.	CLO5

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming/Practical/Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1 A. M. Kshirsagar, *Multivariate Analysis*, Illustrated Edition, Marcel Dekker, 1972.

2 N. C. Giri, *Multivariate Statistical Inference*. 1st Edition, Academic Press, 2004.

3 R. A. Johnson and D. Wichern, *Applied Multivariate Statistical Analysis*, 7th Edition, Pearson, 2013.

4 T. W. Anderson, *An Introduction to Multivariate Statistical Analysis*, 3rd Edition, John Wiley & Sons, 2009.

5 W. K. Hardly and L. Simor, *Applied Multivariate Statistical Analysis*, 4th Edition,Springer-Verlag Berlin Heidelberg, 2015.

Course Title: Multivariate Analysis (Practical)
Course Code: STA.552
Total Hours: 30

L	T	P	Credits
0	0	2	1

Laboratory experiments will be set in context with the materials covered in theory.

Learning Outcome:

The students will be able

- Understand the basic techniques used in multivariate modelling.
- Explain the concepts of multiple correlation in data.
- Understand the principle of data reduction.

Laboratory Work: Students will be able to

1. To construct variance-covariance matrix using a multivariate data.
2. To demonstration of various types of graphs in multivariate data.
3. Generation of multivariate normal data of the given dependence.
4. To construct correlation matrix of a data.
5. To construction of confidence interval in multivariate normal population.
6. To explore the concept of data reduction via PCA.
7. To demonstrate factor analysis.
8. To explore MANOVA.

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem

solving/Self-learning.

Suggested Readings:

1.A. M. Kshirsagar, *Multivariate Analysis*, Illustrated Edition, Marcel Dekker, 1972.

1. N. C. Giri, *Multivariate Statistical Inference*. 1st Edition, Academic Press, 2004.
2. R. A. Johnson and D. Wichern, *Applied Multivariate Statistical Analysis*, 7th Edition, Pearson, 2013.
3. T. W. Anderson, *An Introduction to Multivariate Statistical Analysis*, 3rd Edition, John Wiley & Sons, 2009.
4. W. K. Hardly and L. Simor, *Applied Multivariate Statistical Analysis*, 4th Edition, Springer-Verlag Berlin Heidelberg, 2015.

Course Title: Design and Analysis of Experiment

Course Code: STA.553

Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning Outcomes: The students will be able to

CLO1: Discuss three basic principles of design of experiments.

CLO2: Apply the concept of balancing.

CLO3: Understand the concept of missing plot techniques.

CLO4: Develop understanding of Balanced Incomplete Block Design, Split- Plot Design and Strip-Plot Design.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 12 Hours	Three basic principles of design of experiments: Randomization, replication and local control. Fixed effect and random effect model. Design useful for elimination of heterogeneity, Completely randomized, randomized complete block design.	CLO1
	Learning Activities: Students will learn about three basic principle of design of experiments. They will also solve problems related to CRD and RCBD.	
II 11 Hours	Balanced incomplete block designs and their applications. Asymptotic relative efficiency of various designs, missing plot technique. Latin squares, Graeco Latin squares design.	CLO2
	Learning Activities: Students will understand the concept of BIBD and solve problems related to Latin square and Graeco Latin Square Design.	

III 11 Hours	Factorial designs, 2^2 and 2^3 factorial designs, confounding, fractional replication.	CLO3
	Learning Activities: Students will understand the concept of Factorial designs and solve problems related to them.	
IV 11 Hours	Nested Designs: Split- plot Design, Strip-plot Design.	CLO4
	Learning Activities: Students will learn about Split- plot design and strip plot design and understand their application in real life.	

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. D. C. Montgomery, *Design and Analysis of Experiment*, 10th Edition, John & sons, Wiley, 2019.
2. D. Raghavarao, *Construction and Combinatorial Problems in Design of Experiments*, Wiley, 1971.
3. M. C. Chakarbarti, *Mathematics of Design and Analysis of Experiments*, Asia Publishing House, 1970.
4. M. N. Dass and N. C. Giri, *Design and Analysis of Experiments*, 2nd Edition, Wiley, 1986.
5. O. Kempthorne, *Design and Analysis of Experiments, 2nd Edition, Vol I-II*, Wiley, 2007.
6. W. G. Cochran and G. M. Cox, *Design of Experiments*, 2nd Edition, John Wiley & Sons, 2003.

Course Title: Design and Analysis of Experiment (Practical)

Course Code: STA.554

Total Hours: 30

L	T	P	Credits
0	0	2	1

Learning Outcome:

The students will be able to

- Explain various models related to design of experiments
- Understand the statistical analysis of various designs
- Discuss the comparison of various designs among themselves.

Laboratory Work: Practical will be set in context with the materials covered in theory using R/SPSS.

- Use one-way ANOVA for testing of mean
- Conduct an experiment of fitting fixed effect model
- Conduct an experiment of fitting mixed effect
- Conduct an experiment for testing for equality of blocks.
- Conduct an experiment for fitting of BIBD

- Conduct an experiment for fitting of LSD
- Conduct an experiment for fitting of Split Plot Design
- Conduct an experiment for fitting of Strip Plot Design

Transaction mode: Lecture/Demonstration/ Co Operative learning/programming / Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Course Title: Econometrics Course
Code: STA.575 Total

L	T	P	Credits
3	0	0	3

Learning outcomes:
The students will be able to

CLO1: Understand the concept of OLS and GLS in general linear models (GLM).

CLO2: Explain problem of autocorrelation, multicollinearity in GLM.

CLO3: Discuss Simultaneous linear equations and identification problem.

CLO4: Get in-depth understanding of 2SLS estimators.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 12 Hours	Nature of econometrics. The general linear model (GLM) and its assumptions. Ordinary least squares (OLS) estimation and prediction. Significance tests and confidence intervals, linear restrictions. Use of dummy variables. Generalized least squares (GLS) estimation and prediction.	CLO1
	Learning Activities: Students will explore various forms of least square estimation techniques and their assumptions.	
II 12 Hours	Auto correlation, its consequences and tests. Estimation and prediction. Multicollinearity problem, its implications and tools for handling the problem. Autoregressive linear regression.	CLO2

	Learning Activities: Students will check whether the model satisfies the assumptions of linear regression model. Students will explore various other forms of regression and solve problems related to them.	
III 10 Hours	Simultaneous linear equations model, examples. Identification problem. Restrictions on structural parameters –rank and order conditions.	CLO3
	Learning Activities: Students will solve problems related to Simultaneous Linear equations.	
IV 11 Hours	Estimation in simultaneous equations model. Recursive systems, 2 SLS estimators, Full information maximum likelihood method. Prediction and simultaneous confidence intervals.	CLO4
	Learning Activities: Students will explore two stage and three stage linear estimators and solve problems related to them.	

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming/Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. A. Koutsyannis, *Theory of Econometrics, Mc Millian, 2004.*
2. D. N. Gujarati, D. Porter and S. Gunasekar, *Basic Econometrics*, 5th Edition, McGraw–Hill, 2017.
3. G. C. Judge, R. C. Hill, W. E. Griffiths, H. Lutkepohl and T. C. Lee, *Introduction to the Theory and Practice of Econometrics,* 2nd Edition, John Wiley & Sons, 1988.
4. J. Kmenta, *Elements of Econometrics*, 2nd Edition, Mac Millan, 1986.
5. J. Johnston, *Econometric Methods*, Mc Graw Hill, 1991.
6. W. H. Greene, *Econometric Analysis,* Prentice Hall, 2003.

Course Title: Stochastic Finance and Machine Learning in Insurance

Course Code: STA.557

Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning Outcomes:

The students will be able to

CLO1: Understand the mechanism of options markets.

CLO2: Explain Brownian motion and Wiener Process.

CLO3: Explain Black- Scholes Model.

CLO4: Discuss various forms of Clustering.

CLO5: Get in-depth understanding of Machine learning algorithms.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 12 Hours	Mechanism of Options markets, Types of Options, Option positions, Derivatives, Underlying Assets, Specification of stock options, Stock option pricing, Factors affecting option prices, Upper and lower bounds for option prices.	CLO1
	Learning Activities: Students will understand various types of options and its position. They will also explore the concept of derivatives and its role in stock market.	
II 11 Hours	Trading strategies involving options, Binomial model: One-step and two-step models, Binomial trees. Risk neutral valuation. Brownian Motion, Weiner Process, Quadratic Variation, Arithmetic and Geometric Brownian motion.	CLO2
	Learning Activities: Students will explore the concept of Binomial model and Brownian motion and its applications by solving problems.	

III 11 Hours	Review of basic properties and related martingales, Applications to insurance problems, Ito Lemma, Ito integral, Applying Ito Lemma. Black-Scholes model: Distribution of rate of returns, volatility, risk neutral pricing.	CLO3
	Learning Activities: Students will understand the concept of martingales and application to insurance sector.	
IV 11 Hours	Basics: Introduction to Machine Learning - Different Forms of Learning Classification: Classification tree, SVM, Instance Based Classification, LDA.	CLO4 & CLO5
	Learning Activities: Students will have hand on experience of various machine learning algorithm and its applications through examples.	

Suggested Readings

1. C. Bishop, *Pattern Recognition and Machine Learning*. Springer, 2010.
2. E. S. Steven, *Stochastic Calculus for Finance I: The Binomial Asset Pricing Models*, Springer, 2005.
4 J. C. Hull and S. Basu, *Options, Futures and Other Derivatives*, 3rd Prentice Hall of India Private Ltd., New Delhi, 2010.
5 J. Han and M. Kamber, *Data Mining: Concept and Techniques,* 3rd Edition, Elsevier, USA, 2012.
4. M. S. Joshi, *The Concept and Practice of Mathematical Finance*, 2nd Edition, Cambridge University Press, 2008.
5. R. O. Duda, P. E. Hart and D. G. Stork, *Pattern Classification,* 2nd edition, Wiley-Blackwell, 2000.
6. S. M Ross, *An Elementary Introduction to Mathematical Finance*, Cambridge University Press, 2005.
7. T. Hastie, R. Tibshirani and J. Friedman, *Elements of Statistical Learning*, 9th Edition, Springer, 2017.
8. T. Mitchell, *Machine Learning*. Mc-Graw Hill, 2017.

Course Title: Entrepreneurship Skills Course

L	T	P	Credits
2	0	0	2

Code: STA.563
Total Hours: 30
Learning Outcomes:

The students will be able to:

CLO1: Understand the basic concepts of entrepreneur, entrepreneurship and its importance.

CLO2: Aware of the issues, challenges and opportunities in entrepreneurship.

CLO3: Develop capabilities of preparing proposals for starting small businesses.

CLO4 Know the availability of various institutional supports for making a new start-up.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 6 Hours	Introduction to entrepreneur and entrepreneurship; Characteristics of an entrepreneur; Characteristics of entrepreneurship; entrepreneurial traits and skills; innovation and entrepreneurship; Types of entrepreneurial ventures; enterprise and society in Indian context. **Learning Activities:** Students will understand about the concept of entrepreneur, characteristics of entrepreneurship	CLO1
II 10 Hours	Importance of women entrepreneurship,working environment, challenges in the path of women entrepreneurs, empowerment. Role of Statisticians in business, industry and government sector. **Learning Activities**: Students will explore the importance of women entrepreneurship and role of statisticians in different domains	CLO2
III 8 Hours	Characteristics of successful statisticians, how to develop the ability to face challenges in the work environment, and the importance of consistent learning for becoming a successful entrepreneur. **Learning Activities:** Students will hand on experience through case studies how to develop habits to become a successful statistician and entrepreneur.	CLO3
IV 6 Hours	Importance of effective communication skills, publicizing statistics and ethics consideration, efficient in doing statistical analysis, Case Studies: systems development studies and observational studies **Learning Activities:** Students will hand on experience through case studies on how to communicate effectively and publicizing statistics in an efficient manner.	CLO4

Suggested Readings:

1. Arora, Renu (2008). Entrepreneurship and Small Business, Dhanpat Rai & Sons Publications.
2. Chandra, Prasaaan (2018). Project Preparation, Appraisal, Implementation, Tata Mc-Graw Hills.
3. Desai, Vasant (2019). Management of a Small Scale Industry, Himalaya Publishing House.
4. Jain, P. C. (2015). Handbook of New Entrepreneurs, Oxford University Press.
5. Srivastava, S. B. (2009). A Practical Guide to Industrial Entrepreneurs, Sultan Chand & Sons.

Course Title: Dissertation Part-1 Course

Code: STA.601
Total Hours: 120

L	T	P	Credits
0	0	8	4

Learning outcomes:

The students will be able to

- develop interest in theoretical and practical research.
- decide their area of research as per their competency.
- get theoretical and practical knowledge of a specific area of research.
- prepare themselves for quality research in any mathematical discipline and allied areas.

Evaluation Criteria:

Dissertation Proposal				
	Marks	**Proposal (30)**	**Presentation (10)**	**Viva-Voce (10)**
Supervisor	**50**			
HoD and Senior faculty member	**50**			

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Course Title: Linear Programming (VAC)

Course Code: MAT.528

Total Hours: 30

L	T	P	Credits
2	0	0	2

Learning outcomes:

The students will be able to

CLO1: Discuss the linear programming problem with formulation.

CLO2: Apply different methods to solve linear programming problems.

CLO3: explore the concept of Duality theory and Sensitivity analysis.

CLO4: Explain transportation problems and assignment problems with their mathematical formulation.

Units/ Hours	Content	Mapping with CLO
I 8 Hours	Formulation of linear programming problems (LPP).Graphical solution to LPPs. Cases of unique and multiple optimal solutions. **Activity:** Students will do formulation of Linear programming problems and find the solutions using graphical methods.	CLO1
II 8 Hours	Feasible solution, basic feasible solutions, Optimal solution, Convex sets, Solution of LPP with Simplex methods. **Activity:** Students will solve linear programming problems with the simplex method.	CLO2
III 6 Hours	The dual problem.Formulation of the dual.Dual Simplex method **Activity:** Students will do exercises related to dual linear programming problems.	CLO3
IV 8 Hours	Transportation and Assignment Problem: Transportation problems, Formulation of transportation problems, Feasible and optimal solution of transportation problems. Assignment problems. **Activity:** Students will do exercises on transportation problems and assignment problems.	CLO4

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Recommended Books:

1. H. A. Taha, *Operations Research - An Introduction,* Macmillan Publishing Company Inc., New York, 2006.
2. K .Swarup, P. K. Gupta and Man Mohan, *Operations Research*, Sultan Chand & Sons, New Delhi, 2001.
3. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, McGraw- Hill, New York, 2001.

Semester IV

Course Title: Dissertation Part-II

Course Code: STA.602

L	T	P	Credits
0	0	40	20

Total Hours: 300

Learning outcomes:

The students will be able to

- gain Theoretical and Practical knowledge of a specific area of research.
- have a good understanding of the subject to pursue research in reputed Institutions of higher learning.
- apply theoretical and practical knowledge to real life situations.
- prepare themselves for collaborative research in India and abroad.
- get Phd positions in reputed universities/institutes at regional/ national/ international level.

Evaluation Criteria:

Dissertation						
	Continuous Assessment		Report	Presentation	Viva-Voce	Total Marks
	Regularity in work	Mid-term evaluative				
Supervisor	10	10	20	05	05	50
HoD, Senior most faculty member and external expert	-	-	30	10	10	50

Evaluation pattern similar to fourth semester dissertation will apply for an internship where the supervisor will award 50% marks and external co- supervisor, HoD and senior-most faculty will award 50% marks.

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching / Experimentation /Tutorial / Problem solving/Self-learning.