Central University of Punjab, Bathinda

M.Sc. STATISTICS

Session 2019-2021

Department of Mathematics and Statistics

SEMESTER I

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
STA.506	Probability and Distribution Theory	Core	4	-	-	4
MAT.506	Real Analysis	Core	4	-	-	4
STA.507	Statistical Methods with Packages	Core	3	-	-	3
STA.508	Statistical Methods with Packages (Practical)	Core	-	-	2	1
MAT.508	Linear Algebra	Foundation	4	-	-	4
STA.511	Operation Research	Core	4	-	-	4
XYZ	Inter-Disciplinary Elective-1 (From Other Departments)	IDC	2	-	-	2
Total			21	-	2	22

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

STA.510	Basic Statistics-I	IDC	2	-	-	2

SEMESTER II

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
STA.521	Statistical Inference-I	Core	3	-	-	3
STA.522	Statistical Inference-I (Practical)	Core	-	-	2	1
STA.523	Sampling Theory	Core	3	-	-	3
STA.524	Sampling Theory (Practical)	Core	-	-	2	1
STA.525	Stochastic Processes	Core	4	-	-	4
MAT.526	Complex Analysis	Core	4	-	-	4
STA.526	Linear Models and Regression	Core	2	-	-	2
STA.530	Fundamentals and programming languages	Foundation	3	-	-	3
STA.531	Fundamentals and programming languages (Practical)	Foundation	-	-	2	1
XYZ	Inter-disciplinary (From Other Departments)	IDC	2	-	-	2
Total			21	-	6	24

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

STA.529	Basic Statistics-II	IDC	2	-	-	2

SEMESTER III

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MAT.502	Research Methodology	Foundation	4	-	-	4
STA.543	Seminar	Skill based	2	-	-	2
STA.551	Multivariate Analysis	Core	3	-	-	3
STA.552	Multivariate Analysis (Practical)	Core	-	-	2	1
STA.555	Quality Control and Time Series	Core	3	-	-	3
STA.556	Quality Control and Time Series (Practical)	Core	-	-	2	1
STA.560	Non-parametric Inference	Core	4	-	-	4
STA.571	Statistical Inference-II	Core	3	-	-	3
STA.572	Statistical Inference-II(Practical)	Core	-	-	2	1
MAT.553	Numerical Analysis	DE	3*	-	-	3
MAT.554	Numerical Analysis (Practicals)*		-	-	2	1
STA.558	Actuarial Statistics		4	-	-	4
STA.559	Reliability theory		4	-	-	4
STA.577	Economic Statistics		4	-	-	4
Total			23 (22*)	-	6 (8*)	26

MAT.554 is compulsory with MAT.553

SEMESTER IV

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
STA.553	Design and Analysis of Experiment	Core	3	-	-	3
STA.554	Design and Analysis of Experiment (Practical)	Core	-	-	2	1
MAT.578	Fundamentals of Analysis and Linear Algebra(DEC)	Compulsory Foundation	-	-	4	2
STA.578	Fundamentals of Statistics(DEC)	Compulsory Foundation	-	-	4	2
STA.599	Project Work	Skill based	-	-	12	6
STA.573	Game Theory and Non-linear Programming	DE	4	-	-	4
STA.574	Statistical Simulation					
MAT.574	Advanced Numerical Analysis					
STA.575	Econometrics					
STA.576	Investment Risk Analysis					
STA.561	Survival Analysis					
MAT.503	Writing Skills using Softwares	VAC	-	-	2	1
XYZ	Value added course II	VAC	1	-	-	1
Total			8	-	24	20

Total Credits for the course: 92

Evaluation Criteria for Theory classes

A. Continuous Assessment: [25 Marks]
   i. Surprise Test (minimum three)- Based on Objective Type Tests (10 Marks)
   ii. Term paper (10 Marks)
   iii. Assignments (5 Marks)

B. Mid Semester Test: Based on Subjective Type Questions [25 Marks]

C. End Semester Test: Based on Subjective Type Questions [25 Marks]

D. End-Term Exam: Based on Objective Type Questions [25 Marks]

Evaluation Criteria for Practical classes

A. Practical file: [10 Marks]

B. Written Exam: [10 Marks]

C. Viva-Voce [5 Marks]

SEMESTER I

L	T	P	Cr
4	0	0	4

Course Code: STA.506
Course Title: Probability and Distribution Theory
Total Hours: 60

Learning Outcomes: The course is designed to equip the students with knowledge of various probability distributions and to develop skills and understanding of various inequalities for further studies.

Unit I **14 Hours**

Random experiments, sample spaces (finite and infinite), events, algebra of events, three basic approaches to probability, combinatorial problems. Axiomatic approach to probability. Product sample spaces, conditional probability, Bayes' formula.

Unit II **16 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.

Unit III **15 Hours**

Bivariate random variable, joint, marginal and conditional p.m.fs. and p.d.fs. Correlation coefficient, conditional expectation. Bivariate normal distributions. Moment generating and probability generating functions. Functions of random variables and their distributions using Jacobian of transformation and other tools. Order statistics and their distributions (univariate and bivariate continuous case only).

Unit IV **14 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. Approximating distribution of a function of a statistic (Delta method).

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, 6th Edition, Oxford & IBH Pub., 1999.

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, Wiley Eastern, 2010.

Course Code: MAT.506
Course Title: Real Analysis
Total Lectures: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: The aim of this course is to make the students learn fundamental concepts of metric spaces, Riemann-Stieltjes integral as a generalization of Riemann Integral, Sequence and series of functions and some basic theorems.

Unit-I **15 Hours**

Set Theory: Finite, countable and uncountable sets, Real number system as a complete ordered field, Archimedean property, supremum, infimum

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 $\Re^k$, Bolzano Weierstrass theorem, Heine Borel theorem, Perfect sets, Cantor set, Separated sets, Connected sets in a metric space, Connected subsets of real line.

Unit-II **15 Hours**

Sequences in Metric spaces: Convergent sequences, Subsequences, Cauchy sequences, Complete metric space, Cantor's intersection theorem, Category of a set and Baire's category theorem. Examples of complete metric space, Banach contraction principle.

Unit-III **15 Hours**

Continuity: Limits of functions (in Metric spaces), Continuous functions, Continuity and compactness, Continuity and connectedness, Discontinuities, Monotonic functions, 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.

Unit-IV **15 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, equicontinuous families of functions, Stone Weierstrass Theorem.

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. Tom 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 Code: STA.507
Course Title: Statistical Methods with Packages
Total Lectures: 60

L	T	P	Cr
3	0	0	3

Learning outcomes: The course is designed to equip the students with various techniques used in summarization and analysis of data and also to give understanding of testing of hypotheses, some important distributions and also non-parametric tests for practical knowledge.

Unit 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. Attributes, independence and association of attributes in 2x2 tables. Linear regression and correlation (Karl Pearson's and Spearman's) and residual plots.

Unit 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.

Unit 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.

Unit IV **10 Hours**

Chi-square test of goodness of fit and independence of attributes. Test of significance for correlation coefficient (one and two sample problem). Testing variance of normal distribution, testing of proportion (one and two sample problem), testing of correlation coefficient (one sample and two sample problem).

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*, 7th Edition, Pearson, 2012.
3. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences*, 10th Edition, Wiley & Sons, 2013.

Course Code: STA.508
Course Title: Statistical Methods with Packages (Practical)
Total Hours: 30

L	T	P	Cr
0	0	2	1

Topics should include graphic representation of statistical data, descriptive statistics, correlation, linear regression model and non-parametric tests.

Transaction mode:

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

Course Code: MAT.508
Course Title: Linear Algebra
Total Hours: 30

L	T	P	Cr
4	0	0	4

Learning outcomes: The main objective is to introduce basic notions in linear algebra that are often used in mathematics and other sciences. The emphasis will be to combine the abstract concepts with examples in order to intensify the understanding of the subject.

Unit I **15 Hours**

Vector spaces, Subspaces, Linear dependence and independence, Basis and dimensions, Coordinates, Linear transformations, Algebra of linear transformations, Isomorphism, Matrix representation of a linear transformation, Change of basis, Rank and nullity of a linear

transformation. Linear functionals, Dual spaces, Transpose of a linear transformation.

Unit II **16 Hours**

Characteristic polynomial and minimal polynomial of a linear transformation, Characteristic values and Characteristic vectors of a linear transformation, Cayley Hamilton theorem, Invariant subspaces, Diagonalization and triangulation of a matrix, Direct sum of subspaces, Invariant Direct sums, Characteristic polynomial and minimal polynomial of block matrices.

Unit III **15 Hours**

Cyclic subspaces and Annihilators, 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. Reduction and classification of quadratic forms.

Unit IV **14 Hours**

Inner product spaces. Norms and distances, Orthonormal basis, Orthogonality, Schwartz inequality, The Gram-Schmidt orthogonalization process. Orthogonal and positive definite matrices. The Adjoint of a linear operator on an inner product space, Normal and self-adjoint operators, Unitary and orthogonal operators.

Transaction mode:

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

Suggested Readings:

1. I. N. Herstein, *Topics in Algebra,* 2nd Edition, Wiley Eastern Limited, New Delhi, 2006.
2. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory,* Cengage Learning, 2004.
3. K. Hoffman and R. Kunze: *Linear Algebra,* 2nd Edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2004.
4. P. B. Bhattacharya, S.K. Jain and S.R. Nagpaul, *First Course in Linear Algebra,* Wiley Eastern, Delhi, 2003.

Course Code: STA.511
Course Title: Operations Research
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: The objective of this course is to acquaint the students with the concept of convex sets, their properties, Linear and nonlinear programming problems. The results, methods and techniques contained in this paper are very well suited to the realistic problems in almost every area

Unit-I **14 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.

Unit-II **16 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 Co-efficient matrix.

Unit-III **16 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 problem, traveling salesman problem.

Unit -IV **14 Hours**

Elementary queuing and inventory models: Steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited waiting space, M/G/1.

Transaction mode:

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

Suggested Readings:

1. 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 Code: STA.510
Course Title: Basic Statistics-I
Total Hours: 30

L	T	P	Cr
2	0	0	2

Learning outcomes: To provide the understanding and use of Statistical techniques for students of other departments.

Unit I **7 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.

Unit II **8 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.

Unit III **7 Hours**

Random experiments, sample spaces (finite and infinite), events, algebra of events, three basic approaches to probability, combinatorial problems. Axiomatic approach to probability. Product sample spaces, conditional probability, Bayes' formula.

Unit IV **8 Hours**

Random variables (discrete and continuous). Distribution Function and its properties, mean and variance. Discrete Distributions: Bernoulli, Binomial, Poisson, geometric, negative binomial, uniform. Continuous Distributions: Uniform, normal, exponential.

Transaction mode:

Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching /Experimentation/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*, 10th Edition, Wiley & Sons, 2013.

SEMESTER II

Course Code: STA.521
Course Title: Statistical Inference - I
Total Hours: 45

L	T	P	Cr
3	0	0	3

Learning outcomes: The aim of this course is to provide a rigorous mathematical and conceptual foundation in the techniques of statistical inference and utilization of these techniques in applications in various real life situations.

Unit I **12 Hours**

Parameters, Parametric models, Random sample and its likelihood, 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.

Unit 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.

Unit III **11 Hours**

Methods of estimation: Method of moments, Maximum likelihood estimators, Properties of maximum likelihood estimators, Cramer-Huzurbazar theorem, Likelihood equation with multiple root, Iterative methods, Least square estimation, E. M. algorithm, Minimum chi-square method.

Unit IV **10 Hours**

An 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.

Transaction mode:

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

Suggested Readings:

1. A. K. M. E. Saleh and V. K. Rohatgi, *An Introduction to Probability and Statistics*, 2nd Edition, Wiley, 2008.
2. B. K. Kale, *A First Course on Parametric Inference*, Narosa Publishing House, 1999.
3. C. R. Rao, *Linear Statistical Inference and its Applications*, 2nd Edition, Wiley, 2002.
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, 2008.

Course Code: STA.522
Course Title: Statistical Inference - I (Practical)
Total Hours: 30

L	T	P	Cr
0	0	2	1

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

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

Course Code: STA.523
Course Title: Sampling Theory
Total Hours: 45

L	T	P	Cr
3	0	0	3

Learning outcomes: The course is designed to equip the students with basic knowledge of different sampling schemes, their mean and variance estimations and also give understanding of non-sampling errors.

Unit 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.

Unit II **12 Hours**

Ratio and regression estimators based on 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.

Unit 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].

Unit 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.

Transaction mode:
Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching /Experimentation/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.
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 Code: STA.524
Course Title: Sampling Theory (Practical)
Total Hours: 30

L	T	P	Cr
0	0	2	1

Experiments based on various sampling techniques and comparison in appropriate practical situations.

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

Course Code: STA.525
Course Title: Stochastic Processes
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: This course is framed to equip the students of M.Sc. Statistics with knowledge of different processes, stationarity as well as basic knowledge of this course.

Unit I **15 Hours**

Introduction to Stochastic Processes. Classification of stochastic processes according to state space and time domain. Markov chains, classification of states of a Markov chain, Chapman-Kolmogorov equations, n-step transition probability matrices and their limits, stationary distribution.

Unit II **15 Hours**

Random walk and gambler's ruin problem. Applications of stochastic processes. Stationarity of stochastic processes, Weakly stationary and strongly stationary processes.

Discrete state space continuous time Markov Processes: Poisson process, Simple Birth Process, Simple Death Process, Simple Birth-Death process.

Continuous State Continuous Time Markov Processes: Wiener process, Kolmogorov- Feller differential equations.

Unit III **16 Hours**

Renewal theory**:** Renewal process, elementary renewal theorem and applications. Statement and uses of key renewal theorem, study of residual lifetime process.

Statistical Inference for Markov Chains: Estimation of transition probabilities.

Unit IV **14 Hours**

Branching process: Properties of generating function of branching process, Probability of ultimate extinction, distribution of population size.

Transaction mode:

Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching /Experimentation/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*, 2nd Ed ,Wiley Eastern Ltd., 1994.
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 Code: MAT.526
Course Title: Complex Analysis
Total Lectures: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: This course is aimed to provide an introduction to the theories for functions of a complex variable. It begins with the exploration of the algebraic, geometric and topological structures of the complex number field. The concepts of analyticity, Cauchy-Riemann equations and harmonic functions are then introduced. Students will be equipped with the understanding of the fundamental concepts of complex variable theory.

Unit-I **15 Hours**

Review of complex number system, algebra of complex numbers, complex plane, function of a complex variable, limit, continuity, uniform continuity,

differentiability, analytic function, Cauchy- Riemann equations, harmonic functions and harmonic conjugate.

Unit-II **15 Hours**

Complex line integral, Cauchy's theorem, Cauchy-Goursat theorem, Cauchy's integral formula and its generalized form, Index of a point with respect to a closed curve, Cauchy's inequality. poisson's integral formula, Morera's theorem. Liouville's theorem, Contour integral, power series, Taylor's series, higher order derivatives, Laurent's series.

Unit-III **15 Hours**

Singularities of analytic functions, Fundamental theorem of algebra, zeroes of analytic function, poles, residues, residue theorem and its applications to contour integrals, branches of many valued functions with arg z, log z, and z^{a}. Maximum modulus principle, Schwarz lemma, open mapping theorem.

Unit-IV **15 Hours**

Meromorphic functions, the argument principle, Rouche's theorem, Mobius transformations and their properties and classification, definition and examples of conformal mappings.

Transaction mode:

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

Suggested Readings:

1. L. V. Ahlfors, *Complex Analysis*, 3rd Edition, Tata McGraw-Hill, 1979.
2. R. V. Churchill & J. W. Brown, *Complex Variables and Applications*, 8th 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.

L	T	P	Cr
2	0	0	2

Course Code: STA.526
Course Title: Linear Models and Regression
Total Hours: 30

Learning outcomes: The concepts and techniques from linear models are of fundamental importance in statistics. The main objective is to introduce estimator in linear models. The emphasis will also be upon the testing of linear hypothesis, linear and non-linear models to intensify the understanding of the subject.

Unit I **7 Hours**

Point and interval estimates, best linear unbiased estimates, construction of confidence intervals of the parameters of linear model.

Unit II **8 Hours**

Gauss-Markoff set-up, normal equations, least squares estimates and their precision, use of g-inverse, statements and applications of fundamental theorems of least squares.

Unit III **7 Hours**

Introduction to fixed, mixed and random effect models. Tests of significance and interval estimates based on least squares theory in one-way and two-way classified data . Analysis of variance (ANOVA*) and* analysis *of* covariance (ANCOVA).

Unit IV **8 Hours**

Bivariate, Multiple and polynomials regression and use of orthogonal polynomials. Residuals and their plots as tests for departure from assumptions of fitness of the model normality, homogeneity of variances.

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

Suggested Readings:

1. A. Sen and M. Srivastava, *Regression Analysis: Theory, Methods, and Applications,* illustrated Edition, Springer, 2014.
2. C. R. Rao, *Linear Statistical Inference and its Applications*, 2nd Edition, Wiley, 2009.
3. D. C. Montgomery, E. A. Peck and G. G. Vining, Introduction to Linear Regression Analysis, 5th Edition, Wiley, 2013.
4. F. A. Graybill, *An Introduction to Linear Statistical Models*, Vol. 1, McGraw-Hill Book, 1961.
5. 5. N. R. Draper and H. Smith, *Applied Regression Analysis*, 3rd Edition, Wiley, 2014.
6. R. D. Cook and S. Weisberg, *Residual and Influence in Regression*, Chapman & Hall, 1982.
7. S. Weisberg, *Applied Linear Regression*, 4th Edition, Wiley, 2013

Course Code: STA.530
Course Title: Computer Fundamentals and Programming Languages
Total Hours: 45

L	T	P	Cr
3	0	0	3

Learning outcomes: The aim of this course is to provide adequate knowledge of fundamentals of computer along with problem solving techniques using C programming. This course provides the knowledge of writing modular, efficient and readable C programs. Students also learn the

utilization of arrays, structures, functions, pointers, file handling and their applications.

Unit-I **10 Hours**

Computer Hardware: Definitions, Historical overview, Technological advancement in computers, Shape of today's computer, Computer as a system. CPU, Primary memory, Secondary storage devices, Input and Output devices,

Unit-II **11 Hours**

Computer Software: Significance of software in computer system, Categories of software – System software, Application software, Compiler, Interpreter, Utility program, Binary arithmetic for integer and fractional numbers, Operating System and its significance.
Introduction to algorithm, Flow charts, Problem solving methods, Need of programming languages.

Unit-III **12 Hours**

C Programming: Historical development of C, C character set, Identifiers and keywords, Data types, Declarations, Statement and symbolic constants, Input-output statements, Preprocessor commands, Operators, Expressions, Library functions, Decision making and loop control statements

Unit-IV **12 Hours**

C Programming: Functions, Storage Classes, Arrays, Strings, Pointers, Structure and Union, File handling.

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

Suggested Readings:

1. B. W. Kerninghan and Ritchie D.M., *The C Programming Language*, 2nd Edition, PHI, New Delhi, 2011.
2. G.B. Shelly, T.J. Cashman and M.E. Vermaat, *Introduction to Computers*, Cengage India Pvt Ltd, 2008.
3. P. Norton, *Introduction to Computers*, Tata McGraw Hill, 2008.
4. V. Rajaraman, *Fundamentals of Computers*, PHI, 2004.
5. Y. Kanetkar , *Let Us C*, 13th Edition, BPB Publications, 2013.

Course Code: STA.531
Course Title: Computer Fundamentals and Programming Languages (Practical)
Total Hours: 30

L	T	P	Cr
0	0	2	1

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

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

Course Code: STA.529
Course Title: Basic Statistics-II
Total Hours: 30

L	T	P	Cr
2	0	0	2

Learning outcomes: The course will helps students from other stream like Microbiological Sciences, Plant Sciences, Animal Sciences etc. to understand testing of hypotheses concept in easy manner. The main objective is to give basic understanding of testing of hypothesis to science students so that they can frame correct Hypothesis in their research work and both parametric and non-parametric tests help them to draw conclusions from the sample.

Unit I **7 Hours**

Meaning, need and importance of statistics. Attributes and variables. Discrete and continuous random variables. Introduction to the Discrete and continuous probability distributions. Binomial, Poisson, Normal, F, Student-t and Chi-square distribution.

Unit II **8 Hours**

Meaning of parameters, test statistic and their sampling distributions. Need of Inferential Statistics.

Estimation: Point Estimation and Confidence Interval. Simple and Composite Hypothesis, Type I error, Type II error, power, level of significance, p-value, acceptance region, rejection region, confidence interval.

Unit III **7 Hours**

Parametric tests: Tests for parameters of Normal population (one sample and two sample problems) z-test, student's t-test, F and chi-square test and one way analysis of variance (ANOVA).

Unit IV **8 Hours**

Non-Parametric tests: One sample: Sign test, signed rank test, Kolmogrov-Smirnov test, run test. Two sample problem: Wilcoxon-Mann-Whitney test, Median test, Kolmogrov-Smirnov test. Kruskal–Wallis test.

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, *An Outline of Statistical Theory*, Vol. 2, The World Press Pvt. Ltd., Calcutta, 2003.
2. E. L. Lehmann and G. Casella, *Theory of Point, Estimation*, Student Edition, John Wiley & Sons, 1986.
3. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences,* 10th Edition, John Wiley & Sons, 2013.

SEMESTER III

Course Code:MAT.502
Course Title: Research Methodology
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: The objective of this course is to equip the students with knowledge of some basic as well as advanced concepts related to research. The course covers preparation of research plan, reading and understanding of scientific papers, scientific writing, research proposal writing, ethics, plagiarism etc.

Unit-I **14 Hours**

Introduction: Meaning, Objectives, Characteristics, Significance, and Types of Research; Research Approaches, Research Methods vs. Research Methodology, Research Process, and Criteria of Good Research.

Unit-II **16 Hours**

Literature Survey and Review**:** Meaning of Literature Survey and Review, Sources of Literature, Methods of Literature Review, and Techniques of Writing the Reviewed Literature. Formulating Research Problem**:** Understanding a Research Problem, Selecting the Research Problem, Steps in Formulation of a Research Problem, Formulation of Research Objectives, and Construction of Hypothesis.

Unit-III **14 Hours**

Research Design: Meaning of need of Research Design, Characteristics of a Good Research Design, Different Research Designs, Basic Principles of Experimental Designs, Data Collection, Processing, and Interpretation.

Unit-IV **16 Hours**

Report Writing**:** Types of Reports – Technical and Popular Reports, Significance of Report Writing, Different Steps in Writing Report, Art of Writing Research Proposals, Research Papers, Project Reports, and Dissertations/Thesis; Basics of Citation and Bibliography/Reference

Preparation Styles; Report Presentation: Oral and Poster Presentations of Research Reports.

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

Suggested Readings:

1. Anderson, J. (2001): *Thesis and Assignment Writing*, 4th ed., Wiley, USA
2. Dawson, Catherine, (2014): *Practical Research Methods,* New Delhi, UBS Publishers' Distributors.
3. Kothari, C.R. and G. Garg (2014): *Research Methodology*: Methods and Techniques, 3rd ed., New Age International Pvt. Ltd. Publisher.
4. Kumar, R. (2014): *Research Methodology – A Step-By-Step Guide for Beginners*, 4th ed., Sage Publications
5. Gray, David E. (2004): *Doing Research in the Real World*. London, UK: Sage Publications.

Course Code: STA.543
Course Title: Seminar
Total Hours: 30

L	T	P	Cr
0	0	2	1

Learning outcomes: The objective of the seminar is to develop presentation and communication skills in the students so that they can complete with the future challenges in teaching, research and application.

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

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

L	T	P	Cr
3	0	0	3

Learning outcomes: This course is framed to equip the students of M.Sc. Statistics with knowledge of multivariate analysis.

Unit I **11 Hours**

Multivariate normal distribution: Definition, conditional & marginal distributions, characteristic function. Random sample from multivariate normal distribution. Maximum likelihood estimators of parameters. Distributions of sample mean vector and variance-covariance matrix and their independence. Null distribution of partial and multiple correlation coefficient. Application in testing and interval estimation.

Unit II **12 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.

Unit 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.

Unit IV **11 Hours**

Generalised 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.

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, 1977.
3. R. A. Johnson and D. Wichern, *Applied Multivariate Statistical Analysis*, 6th Edition, Pearson, 2008.
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 Code: STA.552
Course Title: Multivariate Analysis (Practical)
Total Hours: 30

L	T	P	Cr
0	0	2	1

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

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

Course Code: STA.555
Course Title: Quality Control and Time series
Total Hours: 45

L	T	P	Cr
3	0	0	3

Learning outcomes: This course is framed to equip the students of M.Sc. Statistics with knowledge of industrial statistics as well as application of Time series in our practical life.

Unit 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.

Unit II **11 Hours**

Multiple stream processes: Group control charts. Specification limits and tolerance limits, O.C and ARL of control charts, CUSUM charts using V-mask and decision intervals, economic design of (Mean) chart

Unit 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 for inspection by variables for one-sided and two-sided specifications.

Unit 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. Smoothing techniques, spectral analysis of weakly stationary process. Periodogram and correlogram analysis.

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 and L. A. Johnson, *Forecasting and Time Series Analysis*, Mc Graw Hill, New York, 1976.
2. D. C. Montgomery, *Introduction to Statistical Quality Control*, 5th Edition., John Wiley & Sons, 2005.
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 Code: STA.556
Course Title: Quality Control and Time Series (Practical)
Total Hours: 30

L	T	P	Cr
0	0	2	1

Topics should include problems of Quality Control and Time Series using SPSS.

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

Course Code: STA.560
Course Title: Non-Parametric Inference
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: This course is framed to equip the students of M.Sc. Statistics with non-parametric inference and its various tests. Various measure to measure risk will be studied in this course.

Unit I **15 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.

Unit II **15 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'srank correlation.

Unit III **15 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.

Unit IV **15 Hours**

General two sample location and scale problem: Tests for two-sample location problem: Wilcoxon-Mann-Whitney, Terry-Hoeffding, Vander Waerden, Median tests. Tests for two-sample scale problem: Mood, Klotz, Capon, Ansari-Bradley, Siegel – Tukey and Sukhatme tests. Pitman asymptoitic relative efficiency. Tests for the c-sample problem: Kruskal-Wallis, Jonckheere- Terpstra tests. Concepts of Jackknifing, method of Quenouille for reducing bias, Bootstrap methods.

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 Code: STA.571
Course Title: Statistical Inference –II
Total Hours: 45

L	T	P	Cr
3	0	0	3

Learning outcomes: The aim of this course is to provide a rigorous mathematical and conceptual foundation in the techniques of statistical inference and utilization of these techniques in applications in various real life situations.

Unit I **12 Hours**

Testing of Hypotheses: Basic concepts, Statistical hypothesis, Simple and composite hypothesis, Critical region, Two types of errors, Level of significance, Power of a test. Test function: Randomized and non-randomized tests. Most powerful (MP) test, Neyman-Peasrson (NP) Lemma and its applications.

Unit II **12 Hours**

Uniformly most powerful (UMP) test, Nonexistence of UMP test, Unbiased test and UMP unbiased test, Similar regions and complete sufficient statistics, Construction of most powerful similar regions

Unit III **11 Hours**

Likelihood ratio criterion. Likelihood ratio test for the mean of normal population, LR test for equality of means and variances of two and several normal populations. Wald's sequential probability ratio test (SPRT) with prescribed errors of two types, O.C and A.S.N. functions.

Unit IV **10 Hours**

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

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

Suggested Readings:

1. A. K. M. E. Saleh and V. K. Rohatgi, *An Introduction to Probability and Statistics*, 2nd Edition, Wiley, 2008.
2. B. K. Kale, *A First Course on Parametric Inference*, Narosa Publishing House, 1999.
3. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley International Student Edition, 1988.
4. E. L. Lehmann, *Theory of Point, Estimation*, Student Edition, John Wiley & Sons, 1986.
5. G. Casella and R. L. Berger, *Statistical Inference*, 2nd Edition, Duxbury Thomson Learning, 2008.

Course Code: STA.572
Course Title: Statistical Inference - II (Practical)
Total Hours: 30

L	T	P	Cr
0	0	2	1

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

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

Course Code: MAT.553
Course Title: Numerical Analysis
Total Hours: 45

L	T	P	Cr
3	0	0	3

Learning outcomes: The aim of this course is to teach the applications of various numerical techniques for a variety of mathematical problems occurring in science and engineering. At the end of the course, the students will be able to understand the basic concepts of errors, and numerical methods for the solutions of nonlinear equations, linear systems, interpolation and approximations, numerical integration and differential equations.

Unit-I **11 Hours**

Error Analysis: Definition and sources of errors, Propagation of errors, Sensitivity and conditioning, Stability and accuracy, Floating-point arithmetic and rounding errors.
Numerical Solutions of Algebraic Equations: Bisection method. Fixed-point iteration, Newton's method, Secant method, Convergence and order of convergence

Unit-II **12 Hours**

Linear Systems of Equations**:** Gauss elimination and Gauss-Jordan methods, Jacobi and Gauss- Seidel iteration methods.
Polynomial Interpolation**:** Interpolating polynomial, Lagrange and Newton divided difference interpolation, Error in interpolation, Finite difference formulas, Hermite Interpolation.

Unit-III **11 Hours**

Spline and Approximation**:** Cubic Spline, Least square method, Påde approximation
Eigen Value Problems**:** Power method.
Numerical Differentiation and Integration: Numerical differentiation with finite differences, Trapezoidal rule, Simpson's 1/3 - rule, Simpson's 3/8 rule, Error estimates for Trapezoidal rule and Simpson's rule, Gauss quadrature formulas.

Unit-IV **11 Hours**

Numerical Solution of Ordinary Differential Equations**:** Solution by Taylor series, Picard method of successive approximations, Euler's method, Modified Euler method, Runge- Kutta methods. Finite difference method for boundary value problems.

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

Suggested Readings:

1. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7th Edition, Pearson LPE, 2009.
2. K. Atkinson, *An Introduction to Numerical Analysis*, 2nd Edition, John Wiley & Sons, 1989.
3. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Age International, New Delhi, 2015.
4. R. S. Gupta, *Elements of Numerical Analysis*, 2nd Edition, Cambridge University Press, 2015.
5. R.L. Burden and J. D. Faires, *Numerical Analysis*, 9th Edition, Cengage Learning, 2011
6. S. S. Sastry, *Introductory Methods of Numerical Analysis*, 4th Edition, PHI, 2015.

Course Code: MAT.554
Course Title: Numerical Analysis (Practical)
Total Hours: 30

L	T	P	Cr
0	0	2	1

Learning outcomes: Laboratory experiments will be set in context with the materials covered in theory in C/C++/MATLAB. The students will be able to do programming in C/C++/MATLAB for basic numerical methods of each unit in numerical analysis course MAT.553.

Laboratory Work: Programming exercises on numerical methods using C/C++/MATLAB languages.

1. To detect the interval(s) which contain(s) root of equation f(x)=0 and implement bisection method to find the root of f(x)=0 in the detected interval.
2. To compute the root of equation f(x)=0 using Secant method.
3. 3. To find the root of equation f(x)=0 using Newton-Raphson and fixed point iteration methods.4. To compute the intermediate value using Newton's forward difference interpolation formula.
4. To apply Lagrange method for a data set.
5. To construct divided difference table for a given data set and hence compute the intermediate values.
6. To solve a linear system of equations using Gauss elimination (without pivoting) method.
7. To solve a linear system of equations using the Gauss-Seidel method.
8. To find the dominant eigenvalues and associated eigenvector by Rayleigh power method.
9. To integrate a function numerically using trapezoidal and Simpson's rule.
10. To solve the initial value problem using Euler method.
11. To solve the initial value problem using modified Euler's method.
12. To solve the initial value problem using 2^{nd} and 4^{th} order Runge-Kutta methods.

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

Course Code: STA.558
Course Title: Actuarial Statistics
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: This course is framed to equip the students of M.Sc. Statistics with concept of actuarial science and different premium models.

Unit I **16 Hours**

Probability Models and Life Tables, Loss distributions: modelling of individual and aggregate losses, moments. Fitting of distributions to claims data, deductibles and retention limits, proportional and excess-of-loss reinsurance. Risk models: models for individual claims and their sums, Distribution of aggregate claims, Compound distributions and their applications. Introduction to credibility theory.

Unit II **14 Hours**

Survival function, curtate future lifetime, force of mortality. Multiple life functions, joint life and last survivor status. Multiple decrement model.

Unit III **14 Hours**

Life Contingencies: Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor.

Unit 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.

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching /Experimentation/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*. 3rd Edition, Wiley-Interscience, 2008.
5. S. D. Promislow, *Fundamentals of Actuarial Mathematics*, 2nd Edition, Wiley, 2011.

Course Code: STA.559
Course Title: Reliability Theory
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: The course on Reliability Theory is framed to equip the students of M.Sc. Statistics with knowledge of terms involved in reliability theory as well as concepts and measures.

Unit I **15 Hours**

Reliability concepts and measures: Components and systems, coherent systems, reliability of coherent systems, cuts and paths, modular decomposition, bounds on system reliability, structural and reliability importance of components.

Unit II **15 Hours**

Life distributions and associated survival, conditional survival and hazard rate functions. Exponential, Weibull, gamma life distributions and estimation of their parameters.

Unit III **15 Hours**

Notions of ageing. IFR IFRA, NBU, DMRL, NBUE, and HNBUE classes; their duals and relationships between them. Closures of these classes under formation of coherent systems, convolutions and mixtures.

Unit IV **15 Hours**

Partial orderings: Convex, star, stochastic, failure rate and mean-residual life orderings. Univariate shock models and life distributions arising out of them. Maintenance and replacement policies, availability of repairable systems.

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

Suggested Readings:

1. J. V. Deshpande and S. G. Purohit, *Lifetime Data: Statistical Models and Methods*, 2nd Edition, World Scientific, 2015.
2. J. F. Lawless, *Statistical Models and Methods of Life Time Data*, 2nd Edition, Wiley-Blackwell , 2002.
3. M. Shaked and J. G. Shanthikumar, *Stochastic Orders & Their Applications*, illustrated Edition, Springer Science & Business Media, 2007.
4. R. E. Barlow and F. Proschan, *Statistical Theory of Reliability and Life Testing: Probability Models,* 2nd Edition, To Begin With, 1981.
5. S. Zacks, *Introduction to Reliability Analysis: Probability Models and Statistical Method*, 1st Edition, Springer-Verlag, 2012.

Course Code: STA.577
Course Title: Economic Statistics
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: This course is framed to equip the students of M.Sc. Statistics with applications of statistics in economics. Various measure to measure risk will be studied in this course.

Unit I **15 Hours**

The theory of Consumer Behaviour: Utility function, indifference curves and their properties, price and income elasticities, substitution and income effects.

Unit II **15 Hours**

The Theory of the Firm: Production function, output elasticity, elasticity of substitution. Optimizing behaviour: Output maximization, cost minimization and profit maximization. Cost functions: Short run and long run. Homogeneous production functions: Cobb-Douglas and CES Functions.

Unit III **15 Hours**

Market Equilibrium: The perfect competition. Demand functions, supply functions, commodity market equilibrium. Imperfect competition: Monopoly & equilibrium of the firm under monopoly. Profit Minimizations under Monopoly. Monopolistic competition.

Unit IV **15 Hours**

Size Distribution of Income: A Review. Distribution patterns and descriptive analysis. Income distribution functions: The Pareto law, Pareto –Levy law, week Pareto law, lognormal distribution. Inequality of income, Gini coefficient, Lorenz curve mathematically & its deviation for some well-known income distribution function.

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

Suggested Readings:

1. J. M. Henderson and R. E. Quandt, *Microeconomic Theory-Mathematical Approach*, McGraw-Hill,1980.
2. N. C. Kakwani, *Income Inequality and Poverty: Method of Estimation and Policy Applications*, illustrated Edition, Oxford University Press, 1980.
3. P. Lambert, *The Distribution and Redistribution of Income,* 3rd Edition, Manchester University Press, 2001.
4. P. A. Samuelson and W. D. Nordhaus, *Economics*, 19th Edition, Tata McGraw-Hill, 2010.

SEMESTER IV

Course Code: STA.553
Course Title: Design and Analysis of Experiment
Total Hours: 45

L	T	P	Cr
3	0	0	3

Learning outcomes: The course is designed to equip the students with various types of designs that are used in practical life and to develop greater skills and understanding of analysis of these designs.

Unit I **12 Hours**

Three basic principles of design of experiments: Randomization, replication and local control. Design useful for one-way elimination of heterogeneity. Completely randomized, randomized complete block and balanced incomplete block designs and their applications. Asymptotic relative efficiency, Missing plot technique.

Unit II **11 Hours**

Concepts of balancing, orthogonality, connectedness and properties of C-matrix.General inter and intra block analysis of incomplete block designs. Factorial designs, 2^2 and 2^3 factorial designs, confounding, fractional replication. Design useful for two-way elimination of heterogeneity and their general method of analysis by using fixed effect model, Latin squares, Graeco Latin squares and Youden squares designs.

Unit III **11 Hours**

Missing plot techniques, illustrations of construction of s x s mutually orthogonal Latin squares and balanced incomplete block designs (by using finite geometries, symmetrically repeated differences and known B.I.B. designs).

Unit IV **11 Hours**

Incomplete Block Design: Balanced Incomplete Block Design, Split-plot Design, Strip-plot Design.

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*, 7th Edition, John & sons, Wiley, 2008.
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 Code: STA.554
Course Title: Design and Analysis of Experiment (Practical)
Total Hours: 30

L	T	P	Cr
0	0	2	1

Laboratory experiments will be set in context with the materials covered in theory.
Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching /Experimentation/Tutorial/Problem solving/Self-learning.

Course Code: MAT.578
Course Title: Fundamentals of Analysis and Linear Algebra
Total Hours: 60

L	T	P	Cr
0	0	4	2

Learning outcomes: This course is designed in such a way that the students can prepare themselves for competitive examinations like CSIR-UGC NET, SLET, GATE and other similar type of examinations.

Unit I **14 Hours**

Analysis: Elementary set theory, finite, countable and uncountable sets, Real number system as a
complete ordered field, Archimedean property, supremum, infimum. Sequences and series, convergence, limsup, liminf. Bolzano Weierstrass theorem, Heine Borel theorem. Continuity, uniform continuity, differentiability, mean value theorem. Sequences and series of functions, uniform convergence. Riemann sums and Riemann integral, Improper Integrals.

Unit II **16 Hours**

Advance Analysis: Monotonic functions, types of discontinuity, functions of bounded variation, Lebesgue measure, Lebesgue integral. Functions of several variables, directional derivative, partial derivative, derivative as a linear transformation, inverse and implicit function theorems.
Metric spaces, compactness, connectedness. Normed linear Spaces. Spaces of continuous functions as examples.
Topology: Basis, dense sets, subspace and product topology, separation axioms, connectedness and compactness.

Unit III **14 Hours**

Linear Algebra: Vector spaces, subspaces, linear dependence, basis, dimension, algebra of linear transformations. Algebra of matrices, rank and determinant of matrices, linear equations. Eigenvalues and eigenvectors, Cayley-Hamilton theorem. Matrix representation of linear transformations. Change of basis, canonical forms, diagonal forms, triangular forms, Jordan forms. Inner product spaces, orthonormal basis. Quadratic forms, reduction and classification of quadratic forms

Unit IV **16 Hours**

Complex Analysis: Algebra of complex numbers, the complex plane, polynomials, power series,
transcendental functions such as exponential, trigonometric and hyperbolic functions. Analytic functions, Cauchy-Riemann equations. Contour integral, Cauchy's theorem, Cauchy's integral formula, Liouville's theorem, Maximum modulus principle, Schwarz lemma, Open mapping theorem. Taylor series, Laurent series, calculus of residues. Conformal mappings, Mobius transformations.

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

Suggested Readings:

1. Ajit Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, Narosa, Publishing House, 2014.
2. G.de Bara, *Measure Theory and Integration*, Ellis Horwood Limited, England, 2003.
3. H.L. Royden, *Real Analysis*, Macmillan, New York, 1988.
4. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory,* Cengage Learning, 2004.
5. J. R. Munkres, *Topology- A First Course,* Prentice Hall of India, New Delhi, 1975.
6. K. D. Joshi, *Introduction to General Topology*, Wiley Eastern, Delhi, 1986.
7. K. Hoffman and R. Kunze: *Linear Algebra* 2nd Edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2004.
8. L. V. Ahlfors, *Complex Analysis*, Tata McGraw Hill, 1979.
9. M. A. Armstrong, *Basic Topology*, Springer, Paperback Edition, 2004.
10. McGraw Hill, Kogakusha, International student Edition, 1976.
11. P. B. Bhattacharya, S.K. Jain and S.R. Nagpaul, *First Course in Linear Algebra,* Wiley Eastern, Delhi, 2003.
12. S. C. Malik, *Mathematical Analysis*, Wiley Eastern Ltd., 2010.
13. S. Kumaresan, *Topology of Metric Spaces,* second edition, Narosa Publishing House New Delhi, 2015.
14. S. Ponnusamy, *Foundations of Complex Analysis*, Narosa Publishing House, 2007.
15. Walter Rudin, *Principles of Mathematical Analysis,* 3rd Edition.

Course Code: STA.578
Course Title: Fundamentals of Statistics
Total Hours: 60

L	T	P	Cr
0	0	4	2

Learning outcomes: This course is designed in such a way that the students can prepare themselves for competitive examinations like CSIR-UGC NET, SLET, GATE and other similar type of examinations.

Unit I **14 Hours**

Descriptive statistics, exploratory data analysis.
Sample space, discrete probability, independent events, Bayes theorem. Random variables and distribution functions (univariate and multivariate); Expectation and moments. Independent random variables, marginal and conditional distributions, Characteristic functions. Probability inequalities (Tchebyshef, Markov, Jensen). Modes of convergence, weak and strong laws of large numbers, Central Limit Theorems (i.i.d. case).
Markov chains with finite and countable state space, classification of states, limiting behaviour of n-step transition probabilities, stationary distribution.

Unit II **16 Hours**

Standard discrete and continuous univariate distributions. Sampling distributions. Standard errors and asymptotic distributions, distribution of order statistics and range.
Methods of estimation. Properties of estimators. Confidence intervals. Tests of hypotheses: most powerful and uniformly most powerful tests, Likelihood ratio tests. Analysis of discrete data and chi-square test of goodness of fit. Large sample tests.
Simple nonparametric tests for one and two sample problems, rank correlation and test for independence. Elementary Bayesian inference.

Unit III **16 Hours**

Gauss-Markov models, estimability of parameters, Best linear unbiased estimators, tests for linear hypotheses and confidence intervals. Analysis of variance and covariance. Fixed, random and mixed effects models. Simple and multiple linear regression. Elementary regression diagnostics. Logistic regression.
Multivariate normal distribution, Wishart distribution and their properties. Distribution of quadratic forms. Inference for parameters, partial and multiple correlation coefficients and related tests. Data reduction techniques: Principle component analysis, Discriminant analysis, Cluster analysis, Canonical correlation. Simple random sampling, stratified sampling and systematic sampling. Probability proportional to size sampling. Ratio and regression methods.

Unit IV **14 Hours**

Completely randomized, randomized blocks and Latin-square designs. Connected, complete and orthogonal block designs, BIBD. 2K factorial experiments: confounding and construction.

Series and parallel systems, hazard function and failure rates, censoring and life testing.
Linear programming problem. Simplex methods, duality. Elementary queuing and inventory models. Steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited waiting space, M/G/1.

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

Suggested Readings:

1. K. M. E. Saleh and V. K. Rohatgi, *An Introduction to Probability and Statistics*, 2nd Edition, Wiley, 2008.
2. A. M. Goon, M. K. Gupta and B. Dasgupta, *An Outline of Statistical Theory*, Vol. 2, The World Press Pvt. Ltd., Calcutta, 2003.
3. D. C. Montgomery, *Design and Analysis of Experiment*, Wiley, 2004.
4. G. B. Wetherill, *Sampling Inspection and Quality Control*, Halsted Press, 1977.
5. G. Casella and R. L. Berger, *Statistical Inference*, 2nd Edition, Duxbury Thomson Learning, 2008.
6. J. Medhi, *Stochastic Processes*, 2nd Ed ,Wiley Eastern Ltd., 1994.
7. N. R. Draper and H. Smith, *Applied Regression Analysis*, 3rd Ed., Wiley, 1998.
8. P. L. Meyer, *Introductory Probability and Statistical Applications*, Oxford & IBH Pub., 1975.
9. P. Mukhopadyay, *Theory and Methods of Survey Sampling*, Prentice Hall of India, 1998.
10. R. A. Johnson and D. Wichern, *Applied Multivariate Statistical Analysis*, 5th Edition, Pearson, 2005.
11. S. D. Sharma, *Operations Research,* Kedarnath Amarnath, Meerut, 2009.
12. S. M. Ross, *Introduction to Probability Models*, 11th Edition, 2014.
13. S. M. Ross, *Stochastic Processes,* Wiley Publications, 1996.
14. S. Weisberg, *Applied Linear Regression*, Wiley, 1985.
15. T. W. Anderson, *An Introduction to Multivariate Statistical Analysis*, 2nd Edition, Wiley, 1983.

Course Code: STA.599
Course Title: Project Work
Total Hours: 180

L	T	P	Cr
0	0	12	6

Learning outcomes: The objective of the Project work is to develop research and independent thinking skills, presentation and communication skills in the students so that they can compete with the future challenges in teaching, research and applications.

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

/Experimentation/Tutorial/Problem solving/Self-learning.

Course Code: STA.561
Course Title: Survival Analysis
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: The course gives the application of statistics in handling survival data. The course introduces the concept of censoring and the various distributions used to analyses such data. Various models are also suggested to deal with survival data.

Unit I **15 hours**

Concepts of Type-I (time), Type-II (order) and random censoring likelihood in these cases. Life distributions, exponential, gamma, Weibull, lognormal, Pareto, linear failure rate.

Unit II **15 hours**

Inference for exponential, gamma, Weibull distributions under censoring. Failure rate, mean residual life and their elementary properties. Ageing classes and their properties, bathtub failure rate.

Unit III **15 hours**

Estimation of survival function – Actuarial estimator, Kaplan –Meier estimator, Tests of exponentiality against non-parametric classes: Total time on Test, Deshpande Test.

Unit IV **15 hours**

Two sample problem: Gehan test, Log rank test, Mantel-Haenszel test, Cox's proportional hazards model, competing risks model.

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

Suggested Readings:

1. A. J. Gross and V. A. Clark, *Survival Distribution- Reliability Applications in Bio-medical Sciences*, John Wiley and Sons, 1976.
2. D. R. Cox and D. Oakes, *Analysis of Survival Data*, Chapters 1-4, Taylor and Francis, 1984.
3. J. D. Kalbfleisch and R. L. Prentice, *The Statistical Analysis of Failure Time Data*, John Wiley and Sons, 1980.
4. J. V. Deshpande and S. G. Purohit, *Lifetime Data: Statistical Models and Methods*, 2nd Edition, World Scientific, 2015.
5. M. J. Crowder, *Classical Competing Risks*, Chapman & Hall, CRC, London, 2001.
6. R. G. Miller, *Survival Analysis*, 2nd Edition, Wiley Inter-science, 1998.

Course Code: STA.573
Course Title: Game Theory and Non-Linear Programming
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: This course is framed to equip the students of M.Sc. Statistics with concept of game theory as well as Non-linear Programming problem.

Unit I **15 Hours**

Theory of Games: Characteristics of games, minimax (maximin) criterion and Optimal Strategy. Solution of games with saddle point. Equivalence of rectangular game and Liner Programming. Fundamental Theorem of Game Theory. Solution of mxn games by Linear Programming Method. Solution of 2X2 games without saddle point. Principle of dominance. Graphical solution of (2xn) and (mx2) games.

Unit II **15 Hours**

Non-Linear Programming Problems (NLPP): Unconstrained and constrained (with equality and inequality constraints). Saddle points, Kuhn-Tucker necessary and sufficient conditions of optimality.

Unit III **15 Hours**

Quadratic Programming: Wolfe's and Beale's Method of solutions. Separable programming and its reduction to LPP. Separable programming algorithm. Geometric Programming: Constrained and unconstrained. Complementary geometric programming problems.

Unit IV **15 Hours**

Dynamic Programming: Balman's principle of optimality. Application of dynamic programming in production, Dynamic Programming algorithm. Linear programming and Reliability problems. Goal Programming and its formulation.

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

Suggested Readings:

1. K. Swarup, P. K. Gupta, and M. Mohan, *Operations Research*, Sultan Chand & Sons, New Delhi, 2001.
2. N. S. Kambo, *Mathematical Programming, Dynamic Programming,* 1984.
3. O. L. Mangasarian, *Nonlinear Programming*, Tata McGraw-Hill New Delhi, 1969.
4. R. Bellman, *Dynamic Programming,* Reprint edition, Dover Publications Inc, 2003.
5. R. Bellman, and S. Dreyfus, *Applied Dynamic Programming*, Princeton University Press, Princeton, 2016.
6. S. D. Sharma, *Operations Research,* Kedarnath Amarnath, Meerut, 2009.

Course Code: STA.574
Course Title: Statistical Simulation
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: This course is framed to equip the students of M.Sc. Statistics with knowledge of random number generation using congruential and Monte Carlo Methods as well as basic knowledge of this course.

Unit I **16 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.

Unit II **14 Hours**

Random Number Generation**:** Congruential generators, statistical tests for pseudo random numbers.

Unit III **16 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.

Unit IV **14 Hours**

Monte Carlo integration and variance reduction techniques : Hit or miss Monte Carlo method, sample mean Monte Carlo method, Jacknife Method.

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, *Simulation and Monte Carlo Method*, John Wiley & Sons, 1981.
4. T. T. Julius and R. C. Gonzalesz, *Pattern Recognition Principles*, Addison – Wesley Publishing Company, 1997.

Course Code: MAT.574
Course Title: Advanced Numerical Analysis
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: The objective of the course is to familiarize the students about some advanced numerical techniques e.g. solving systems of nonlinear equations, linear system of equations, eigenvalue problems,

interpolation and approximation techniques and their use in differentiation and integration, differential equations etc.

UNIT- I **16 Hours**

Non-Linear Equations: Methods for multiple roots, Muller's, Iteration and Newton-Raphson method for non-linear system of equations, and Newton-Raphson method for complex roots. Polynomial Equations: Descartes' rule of signs, Birge-Vieta, Bairstow and Giraffe's methods. System of Linear Equations**:** LU Decomposition methods, SOR method with optimal relaxation parameters.

UNIT-II **14 Hours**

Eigen-Values of Real Symmetric Matrix: Similarity transformations, Gerschgorin's bound(s) on eigenvalues, Jacobi, Givens and Householder methods. Interpolation and Approximation: B - Spline and bivariate interpolation, Gram-Schmidt orthogonalisation process and approximation by orthogonal polynomial, Legendre and Chebyshev polynomials and approximation.

UNIT- III **14 Hours**

Differentiation and Integration: Differentiation and integration using cubic splines, Romberg integration and multiple integrals. Ordinary Differential Equations: Shooting and finite difference methods for second order boundary value problems.

UNIT- IV **16 Hours**

Partial Differential Equations: Finite difference methods for Elliptic, Parabolic and Hyperbolic partial differential equations.

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

Suggested Readings:

1. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7th Edition, Pearson LPE, 2009. K. Atkinson, *An Introduction to Numerical Analysis*, John Wiley & Sons, 2nd Edition, 1989.
2. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Age International, New Delhi, 2015.
3. R.L. Burden and J. D. Faires, *Numerical Analysis*, 9th Edition, Cengage Learning, 2011.
4. R. S. Gupta, *Elements of Numerical Analysis*, 2nd Edition, Cambridge University Press, 2015.
5. S.D. Conte and Carl D. Boor, *Elementary Numerical Analysis: An Algorithmic Approach*, Tata McGraw Hill, 2005.

Course Code: STA.575
Course Title: Econometrics
Total Hours: 45

L	T	P	Cr
4	0	0	4

Learning outcomes: This course is framed to equip the students of M.Sc. Statistics with concept of econometrics as well as practical usage of this course.

Unit 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 and seasonal adjustment. Generalized least squares (GLS) estimation and prediction. Heteroscedastic disturbances.

Unit II **12 Hours**

Auto correlation, its consequences and tests. Estimation and prediction. Multicollinearity problem, its implications and tools for handling the problem. Ridge regression. Linear regression with stochastic regressors. Instrumental variable estimation, errors in variables. Autoregressive linear regression. Distributed lag models: Partial adjustment, adaptive expectation and Koyck's approach to estimation.

Unit III **10 Hours**

Simultaneous linear equations model, examples. Identification problem. Restrictions on structural parameters –rank and order conditions. Restriction on variance and co-variances.

Unit IV **11 Hours**

Estimation in simultaneous equations model. Recursive systems, 2 SLS estimators, k-class estimators. 3SLS estimation. Full information maximum likelihood method. Prediction and simultaneous confidence intervals. Idea of Monte Carlo studies and simulation.

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, *Basic Econometrics*, 4th Edition, McGraw−Hill, 2004.
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 Code: STA.576
Course Title: Investment Risk Analysis
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: This course is framed to equip the students of M.Sc. Statistics with concept of risk involved in investment. Various measures to measure risk will be studied in this course.

Unit I **15 Hours**

The Investment Environment: Real and Financial. Assets, Financial investment companies. Process of building an Investment Portfolio, Risk-Return Tradeoff, Financial Intermediaries, Investment Companies, Investment Bankers. Globalization, Securitization, Money market, Fixed income. Equity securities, stocks and bonds, Treasury notes, Market Indices, Derivative Markets. Call option, Put option, Future Contract, Trade of Securities.

Unit II **15 Hours**

Interest Rates, Rates of return, Risk and Risk Premium. Time series analysis of Past Rates of return; The Historical Record of Returns on Equities and long term bonds. Measurement Of risk non-normal distributions, Value at Risk (VaR), Risk Aversion and Capital Allocation of Risky Assets, Optimal Risky Portfolios.

Unit III **15 Hours**

Capital Asset Pricing Model (CAPM), Risk Assessment using Multifactor models. Arbitrage Pricing Theory (APT), Random Walks and the Efficient Market Hypothesis (EMH), Bond process and yields. The Term Structure of Interest Rates. Managing Bond Portfolios.

Unit IV **15 Hours**

Brief Introduction of the topics: Options markets, Option Contracts, Option Valuation. Binomial Option Pricing, Black-Scholes Option Formula, Valuation, Future Markets. Hedging, Swaps.

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

Suggested Readings:

1. D. Ruppert, *Statistics and Finance*, Springer, 2004.
2. H. H. Panjer, *Financial Economics with Application to Investments, Insurance and Pensions*, The Actuarial Foundation , 2001.
3. M. Baxter and A. Rennie, *Financial Calculus: An Introduction to Derivative Pricing*, Cambridge University Press, 1996.
4. Z. Bodie, A. Kane and A. J. Marcus, *Investments*, 8th Edition, Tata McGraw Hill, 2009

Course Code: MAT.503
Course Title: Writing Skills using Softwares
Total Hours: 30

L	T	P	Cr
0	0	2	1

Learning outcomes: The main objective of this course is provide a basic knowledge of LaTeX and its applications in building of teaching materials and scientific reports.

Unit-I **8 Hours**

Installation of the software LaTeX, Understanding LaTeX compilation and LaTeX editors, Basic syntax, Writing mathematical equations, Matrices, Tables, Inclusion of graphics into LaTeX file.

Unit-II **8 Hours**

Page configurations**:** Title, Abstract, Keywords, Chapter, Sections and Subsections, References and their citations, Labeling of equations, Table of contents, List of figures, List of tables, Page numbering, Generating index.

Unit-III **6 Hours**

Packages**:** amsmath, amssymb, amsthm, amsfonts, hyperrefer, graphic, color, xypic, latexsym, natbib, setspace, multicol, subcaption, url, verbatim, tikz, and geometry. Classes**:** Article, Report, Book, Letter, Slides, Beamer.

Unit-IV **8 Hours**

Applications: Writing reports, books, articles/ research papers, thesis, and official letters. Making simple and modern resumes, figures, question papers, and presentations.

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.