Central University of Punjab, Bathinda

M.Sc. STATISTICS

Session: 2020-2022

Department of Mathematics and Statistics

School of Basic and Applied Sciences

M.Sc. (Statistics) Programme

Program Outcomes:

After completion of the program, students will be able to

- develop a broad understanding of recent statistical theories, tools and techniques.
- apply statistical techniques in various fields.
- independently develop and execute statistical research.
- compete at national/international level for research/jobs in area of statistics.

Semester I

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MAT.506	Real Analysis	Core	4	0	0	4
STA.507	Statistical Methods with Packages	Core	3	0	0	3
STA.508	Statistical Methods with Packages (Practical)	Core	0	0	2	1
MAT.508	Linear Algebra	Foundation	4	0	0	4
STA.512	Probability Theory	Core	4	0	0	4
STA.513	Distribution Theory	Core	4	0	0	4
XYZ	Inter-Disciplinary Elective-1 (From Other Departments)	IDC	2	0	0	2
Total			**21**	**0**	**2**	**22**

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

STA.510	Basic Statistics-I	IDC	2	0	0	2

Semester II

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
STA.521	Statistical Inference-I	Core	3	0	0	3
STA.522	Statistical Inference-I (Practical)	Core	0	0	2	1
STA.523	Sampling Theory	Core	3	0	0	3
STA.524	Sampling Theory (Practical)	Core	0	0	2	1
STA.525	Stochastic Processes	Core	4	0	0	4
MAT.526	Complex Analysis	Core	4	0	0	4
STA.526	Linear Models and Regression	Core	4	0	0	4
STA.530	Fundamentals of Programming languages	Foundation	3	0	0	3
STA.531	Fundamentals of Programming languages (Practical)	Foundation	0	0	2	1
XYZ	Inter-disciplinary (From Other Departments)	IDC	2	0	0	2
Total			**23**	**0**	**6**	**26**

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

STA.529	Basic Statistics-II	IDC	2	0	0	2

Semester III

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MAT.502	Research Methodology	Foundation	4	0	0	4
STA.543	Seminar	Skill based	0	0	0	2
STA.551	Multivariate Analysis	Core	3	0	0	3
STA.552	Multivariate Analysis (Practical)	Core	0	0	2	1
STA.555	Quality Control and Time Series	Core	3	0	0	3
STA.556	Quality Control and Time Series (Practical)	Core	0	0	2	1
STA.571	Statistical Inference-II	Core	3	0	0	3
STA.572	Statistical Inference-II(Practical)	Core	0	0	2	1
xxx	Value added course I	VAC	0	0	2	1
MAT.528	Linear Programming	VAC	1	0	0	1
MAT.553	Numerical Analysis	Discipline Elective	3*	0	0	3
MAT.554	Numerical Analysis (Practical)*		0	0	2	1
STA.511	Operation Research		4	0	0	4
STA.558	Actuarial Statistics		4	0	0	4
STA.509	Demography and Vital Statistics		4	0	0	4
STA.577	Economic Statistics		4	0	0	4
STA.559	Reliability Theory		4	0	0	4
Total			**17 (16*)**	**0**	**8 (10*)**	**23**

MAT.554 is compulsory with MAT.553

M.Sc. Statistics (Semester IV)

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
STA.553	Design and Analysis of Experiment	Core	3	0	0	3
STA.554	Design and Analysis of Experiment (Practical)	Core	0	0	2	1
STA.575	Econometrics	Core	4	0	0	4
MAT.578	Fundamentals of Analysis and Linear Algebra	DEC	0	4	0	2
STA.578	Fundamentals of Statistics	DEC	0	4	0	2
STA.599	Project Work	Skill based	0	0	0	6
STA.560	Non-parametric Inference	Discipline Elective	4	0	0	4
STA.574	Statistical Simulation					
STA.576	Investment Risk Analysis					
STA.561	Survival Analysis					
XYZ	Value added course II	VAC	1	0	0	1
MAT.528	Linear Programming For other Deptt	VAC	1	0		1
Total			**12**	**8**	**2**	**23**

Total Credits: 94

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: [15 Marks]
B. Practical Exam: [75 Marks]
C. Viva-Voce [10 Marks]

Semester I

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

L	T	P	Credits
4	0	0	4

Learning outcomes: The students will be able to

- Define countable and uncountable sets and related results.
- Define metric spaces with examples.
- Illustrate various properties of compact sets and connected sets.
- Explain concepts of convergent sequences and continuity in metric spaces.
- Study of Riemann Stieltje's Integral in detail.

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

L	T	P	Credits
3	0	0	3

Learning outcomes: The students will be able to

- Learn the different methods of data presentation.
- Understand about the measures of central tendency.
- Explore the exact sampling distributions.
- Exercise the application of testing in real-life problems.
- Knowing the concept of chi-square goodness of fit.

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 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 and non-parametric tests.

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

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

L	T	P	Credits
0	0	2	1

Learning outcomes:
The students will be able to

- Review the basic notions in linear algebra that are often used in mathematics and other sciences
- Define Vector spaces, Subspaces and related results.
- Define Linear transformations and characteristic polynomials with examples.
- Illustrate various properties of canonical forms.
- Study of Inner product spaces
- Explain concepts of the Gram-Schmidt orthogonalization process.

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 I **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/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. I. S. Luthar and I. B. S. Passi, *Algebra: Rings*, Volume 2, Narosa Publishing House, 2000.
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, *Basic Abstract Algebra,* Wiley Eastern, Delhi, 2003.
5. V. Bist and V. Sahai, *Linear Algebra,* Narosa, Delhi, 2002.

Course Title: Probability Theory
Course Code: STA.512
Total Hours: 60

L	T	P	Credits
4	0	0	4

Learning Outcomes: The students will be able to

- Understand the concept of sigma field, probability measure and probability space.
- Explore the concept of distribution and random variables.
- Establish the various moments inequalities.
- Learn the concept of convergence of sequences of random variables.

Unit I **14 Hours**

Classes of sets, field and sigma fields, limit of sequences of sets, sigma field generated by a class of subsets, Borel fields. Probability measure, probability space, continuity of a probability measure. Real and vector-valued random variables. induced probability space

Unit II **16 Hours**

Probability distribution, Distribution functions of discrete, continuous and mixed type random variables, decomposition of a distribution. Expectation of random variable and its properties. Linear properties of Expectations, Inequalities: Jensen's, Chebychevs, Markov, Hȍlders and Lyapounov inequalities.

Unit III **14 Hours**

Independence of events and random variables, sequence of independent events, Π–systems and λ-system of events, Dykin's theorem(without proof) independence of rvs of events. Borel zero-one law, Borel-Cantelli Lemma, Kolmogorov zero-one law.

Unit IV **16 Hours**

Various modes of convergence of sequences of random variables (in probability, almost surely, in rth mean), Implication between modes of convergence. Slutsky's theorem. Monotonic convergence theorem and dominated convergence theorem. Fatous lemma. Law of large number: weak law of large number, Tchebychev and Khintchine theorem (with proof) and strong law of large number (without proof). Inversion, Continuity and Uniqueness theorems of Characteristics function. Demoivre Laplace Central Limit Theorem, Liapounovs and Lindeberg's CLT (without proof).

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

Suggested Readings:

1. K. L. Chung, A Course in Probability Theory, 3rd Edition, Academic Press, 2001.
2. P. Billingsley, Probability and Measure, 3rd Edition, Wiley Series in Probability and Mathematical Statistics. 2008.
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 Title: Distribution Theory
Course Code: STA.513
Total Hours: 60

L	T	P	Credits
4	0	0	4

Learning Outcomes: The students will be able to

- Explain random experiments, probability distributions.
- Classify various probability distributions.
- Make use of discrete and continuous distributions.
- Justify compound, truncated and mixture distributions.
- Discuss order statistics and convolution of two distributions.

Unit I **14 Hours**

Discrete distributions: Uniform, Bernoulli, Binomial, geometric, Negative Binomial, hyper-geometric, Poisson, Continuous Distributions: Uniform, Uniform, normal, exponential, gamma, Beta, Cauchy, Weibull, Pareto, Laplace and Lognormal, Pareto, Cauchy, logistic distributions their properties and applications.

Unit II **16 Hours**

Discrete and continuous bivariate random variables: Definitions, Computation of probabilities of various events, marginal, conditional, product moments and correlations. The p. d. f. of a bivariate normal distribution, marginal and conditional distributions, conditional expectation and conditional variance, regression lines of Y on X and X on Y.

Unit III **15 Hours**

Moment generating and probability generating functions. Functions of random variables and their distributions using Jacobian of transformation and other tools. Compound, truncated and mixture distributions. Convolutions of two distributions.

Unit IV **14 Hours**

Order statistics and joint, marginal and conditional distribution distributions (univariate and bivariate continuous case only).The distribution of sample range.

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

Suggested Readings:

1. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley International Student Edition, 1988.
2. G. Gupta and D. Gupta, *An Outline of Statistical Theory*, Vol. I, World Press, 1991.
3. H.A. David and H. N. Nagaraja, *Order Statistics*. John Wiley & Sons, Inc., 1970.
4. I. Miller and M. Miller, *Mathematical Statistics*, 6th Edition, Oxford & IBH Pub., 1999.

5. P. Mukhopadhyay: *Mathematical Statistics*, New central Book Agency (P) Ltd. Calcutta, 1996.
6. P. L. Meyer, *Introductory Probability and Statistical Applications*, 2nd Edition, Oxford & Lbh, 2017.
7. S. M. Ross, *Introduction to Probability Models*, 11th Edition, 2014.
8. V. K. Rohtagi and A. K. M. E. Saleh, *An Introduction to Probability Theory and Mathematical Statistics*, Wiley Eastern, 2010.

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

L	T	P	Credits
2	0	0	2

Learning outcomes: The student will be able to

- Explain descriptive statistics, probability distributions.
- Classify measures of central tendency and dispersion.
- Make use of basic approaches to probability.
- Justify axiomatic approach to probability.
- Discuss application of discrete and continuous random variables.

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

L	T	P	Credits
3	0	0	3

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

Learning outcomes: The students will be able to

- Learn different estimation techniques.
- Identify a good estimator.
- Learn the concept of MVUE and UMVUE.
- Establish various properties of likelihood estimators.
- Understand the concept of statistical inference under Bayesian framework.

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

L	T	P	Credits
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/Team teaching/Tutorial/Problem solving/Self-learning.

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

L	T	P	Credits
3	0	0	3

Learning Outcomes: The students will be able to

- Explain various sampling techniques.
- Classify among SRSWOR, SRSWR, stratified etc.
- Make use of Two-stage sampling and double sampling techniques.
- Justify PPS WR/WOR methods.
- Discuss Yates, Grundy and Desraj estimators as well as sampling and 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, 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

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.

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 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 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.

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

L	T	P	Credits
4	0	0	4

Learning Outcomes: The students will be able to

- Explain Stochastic Processes.
- Classify among various forms of stochastic processes.
- Make use of random walk and counting process.
- Justify Markov Chain
- Discuss Renewal and elementary renewal process.

Unit I **15 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.

Unit II **17 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.
Statistical Inference for Markov Chains: Estimation of transition probabilities.

Unit III **16 Hours**

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: Brownian motion process, Wiener Process and its properties

Unit IV **12 Hours**

Renewal theory**:** Renewal process, elementary renewal theorem and applications. Statement and uses of key renewal theorem, study of residual lifetime process. Definition and examples of discrete time branching process.

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 Title: Complex Analysis
Course Code: MAT.526
Total Lectures: 60

L	T	P	Credits
4	0	0	4

Learning outcomes:

The students will be able to

- Recall complex number system and algebra of complex variables
- Define function of complex variable and Analytic functions Cauchy Riemann equations
- Explain the relationships between Cauchy Riemann equations and analytic functions.
- Understand the concept of complex line integral and related results
- Discuss Mobius transformations and their properties

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. 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/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial /Problem solving/E-team teaching/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.

Course Title: Linear Models and Regression
Course Code: STA.526
Total Hours: 60

L	T	P	Credits
4	0	0	4

Learning Outcomes: The students will be able to

- Explain linear model.
- Classify between point and interval estimates.
- Make use of g-inverse for estimation of parameters in linear models.
- Justify ANOVA, ANCOVA, Logit, Probit model
- Discuss Bivariate, Multiple and polynomials regression.

Unit I **14 Hours**

Linear model, least squares estimates, best linear unbiased estimates, Gauss-Markoff set-up, normal equations, Point and interval estimates construction of confidence intervals of the parameters of linear model.

Unit II **14 Hours**

Interval estimation for regression coefficients β_0, β_1 and σ^2, Interval estimation of the mean response, R^2. Use of g-inverse, statements and applications of fundamental theorems of least squares.

Unit III **17 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). Fundamental concept of generalized linear model (GLM), exponential family of random variables. Link functions such as Logit, Probit, binomial.

Unit IV **15 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. 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 Title: Fundamentals and Programming Languages
Course Code: STA.530
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning Outcomes: The students will be able to

- Explain Historical and technological advancement in computers.
- Classify various categories of software.
- Make use of C character set, Identifiers and keywords, Data types, Declarations, Statement and symbolic constants, Input-output statements.

- Discuss Functions, Storage Classes, Arrays, Strings, Pointers, Structure and Union, File handling.

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

L	T	P	Credits
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 Title: Basic Statistics-II
Course Code: STA.529
Total Hours: 30

L	T	P	Credits
2	0	0	2

Learning outcomes: The students will be able to

- Define basic concept of descriptive statistics.
- Classify various discrete and continuous random variables.
- Make use of different test statistic for testing of different hypotheses.
- Discuss parametric and non-parametric tests 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 Title: Research Methodology
Course Code: MAT.502
Total Hours: 60

L	T	P	Credits
4	0	0	4

Learning outcomes: The students will be able to

- Explain the various terms like as objective, meaning of research, significance research etc. which is used in research.
- Review the basic concepts of literature survey and formulation research problems.
- Discuss various types of reports and significance of report writing.

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 and Need for 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/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial /Problem solving/E-team teaching/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. Gray, David E. (2004): *Doing Research in the Real World*. London, UK: Sage Publications.

4. Kothari, C.R. and G. Garg (2014): *Research Methodology*: Methods and Techniques, 3rd ed., New Age International Pvt. Ltd. Publisher
5. Kumar, R. (2014): *Research Methodology – A Step-By-Step Guide for Beginners*, 4th ed., Sage Publications

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

L	T	P	Credits
0	0	0	2

Learning outcomes:.
Upon successful completion of this course, the student will be able to:
1. Understand the aspects of seminar presentation..
2. presentation and communication skills.
3. complete with the future challenges in teaching, research and application.

Evaluation Criteria:
The evaluation criteria for "Seminar" shall be as follows:

S. No.	Criteria	Marks
1.	Content of presentation	20
2.	Presentation & Communication Skills	20
3.	Handling of queries	10
Total		50

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

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
- Learn various important properties of multivariate normal distribution.
- Analyse multivariate data.
- Understand multivariate hypothesis tests and infer appropriate conclusions.
- Use the Wishart distribution in real applications.
- Explore the principles of data reduction techniques.

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 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.

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

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

L	T	P	Credits
3	0	0	3

Learning outcomes: The students will be able to

- Understand the concept of quality assurance, technology and productivity.
- Explain $\bar{X}$ and R charts, analysis of pattern on control charts, control chart for attributes- np, p, c and u charts
- Explain CUSUM, Group control charts, O. C. curve and ARL of control charts.
- Discuss Dodge's continuous sampling inspection plans .
- Get in-depth understanding of Time Series models.

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: $\underline{X}$ 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 Title: Quality Control and Time Series (Practical)
Course Code: STA.556
Total Hours: 30

L	T	P	Credits
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/Tutorial/Problem solving/Self-learning.

Learning Outcome. Students will be able to
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 using V-mask and decision intervals.
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

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

L	T	P	Credits
3	0	0	3

Learning Outcomes: The students will be able to
- Understand the basics of hypothesis testing, calculation of type 1 and type 2 error.
- Construct MP and UMP test.
- Understand about the likelihood ratio test.
- Understand the problem of Interval Estimation.

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

L	T	P	Credits
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 Title: Numerical Analysis
Course Code: MAT.553
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes: The students will be able to

- Review the basic concepts of various numerical techniques for a variety of mathematical problems occurring in science and engineering.
- Explain the basic concept of errors .
- Review the numerical techniques for interpolation and approximations with examples.
- Explain the concept of numerical integration and solutions of 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/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

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

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

L	T	P	Credits
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. 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.
5. To apply Lagrange method for a data set.
6. To construct divided difference table for a given data set and hence compute the intermediate values.
7. To solve a linear system of equations using Gauss elimination (without pivoting) method.
8. To solve a linear system of equations using the Gauss-Seidel method.
9. To find the dominant eigenvalues and associated eigenvector by Rayleigh power method.
10. To integrate a function numerically using trapezoidal and Simpson's rule.
11. To solve the initial value problem using Euler method.
12. To solve the initial value problem using modified Euler's method.
13. To solve the initial value problem using 2nd and 4th order Runge-Kutta methods.

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

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

L	T	P	Credits
4	0	0	4

Learning outcomes: The students will be able to

- Discuss the concept of convex sets and linear programming problem with formulation.
- Apply different methods to solve linear programming problem.
- Understand the concept of Duality theory and Sensitivity analysis.
- Explain transportation problem and assignment problem with their mathematical formulation.
- Apply methods to test the optimality of transportation problem.
- Develop understanding of Queuing and inventory models.

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

L	T	P	Credits
4	0	0	4

Learning outcomes: The students will be able to

- Understand the concept of probability models and life tables.
- Explain risk models for individual claims and distribution of aggregate claims.
- Explain survival, multiple, joint life and last survivor functions.
- Discuss various forms of rate of interest and their applications.
- Get in-depth understanding of assurance and annuity contracts.

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**

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 Title: Demography and Vital Statistics
Course Code: STA.509
Total Hours: 60

L	T	P	Credits
4	0	0	4

Learning outcomes: The students will be able to

- Understand the concept of population theories.
- Explain stochastic models for reproduction.
- Explain different measures of mortality.
- Discuss stochastic models for migration.
- Get in-depth understanding of methods for population projection.

Unit I **15 Hours**

Population Theories: Coverage and content errors in demographic data, use of balancing equations and Chandrasekharan-Deming formula to check completeness of registration data, Adjustment of age data use of Myer and UN indices Population composition, dependency ratio.

Unit II **15 Hours**

Measures of fertility: stochastic models for reproduction, distribution of time to first birth, inter-live birth intervals and of number of births, estimation of parameters, estimation of parity progression ratio from open birth interval data.

Unit III **15 Hours**

Measures of Mortality: Construction of abridged life tables, Distribution of life table functions and their estimation. Stable and quasi-stable populations, intrinsic growth rate Models for population growth and their fitting to population data. Stochastic models for population growth.

Unit IV **15 Hours**

Stochastic models for migration and for social and occupational mobility based on Markov chains. Estimation of measures of mobility. Methods for population projection. Use of Leslic matrix.

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

Suggested Readings:

1. D. I. Bartholomew, *Stochastic Models for Social Process*, John Wiley, 1982.
2. M. Spiegelman, *Introduction to Demography Analysis*, Harvard University press, 1969.
3. N. Keyfitz, *Applied Mathematical Demography*, Springer Verlag, 1977.
4. N. Keyfitz, J. A. Beckman, *Demography through Problems*, S-Verlag New York, 1984.
5. P. R. Cox, *Demography*, Cambridge University press, 1970.
6. R. Ramkumar, *Technical Demography*, New Age International, 1986.
7. S. Biswas, *Stochastic Process in Demography and Applications*, Wiley Eastern Ltd., New Delhi, 1988.

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

L	T	P	Credits
4	0	0	4

Learning outcomes: The students will be able to

- Understand the concept of customer behaviour.
- Explain homogeneous production functions.
- Explain Cobb-Douglas and CES functions.
- Discuss the concept of profit minimization under monopoly.
- Get in-depth understanding of various laws of income distribution.

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.
6. S. Zacks, *Introduction to Reliability Analysis: Probability Models and Statistical Method*, 1st Edition, Springer-Verlag, 2012.

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

L	T	P	Credits
4	0	0	4

Learning outcomes: The students will be able to

- Understand the concept of population theories.
- Explain stochastic models for reproduction.
- Explain different measures of mortality.
- Discuss stochastic models for migration.
- Get in-depth understanding of methods for population projection.

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.

Semester IV

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

- Discuss three basic principle of design of experiments.
- Apply the concept of balancing.
- Understand the concept of missing plot techniques.
- Develop understanding of Balanced Incomplete Block Design, Split-Plot Design and Strip-Plot Design.

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 Title: Design and Analysis of Experiment (Practical)
Course Code: STA.554
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 to

- 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

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

L	T	P	Credits
3	0	0	3

Learning outcomes: The students will be able to

- Understand the concept of OLS and GLS in general linear models (GLM).
- Explain problem of autocorrelation, multicollinearity in GLM.

- Explain Ridge regression, Linear regression with stochastic regressors.
- Discuss Simultaneous linear equations and identification problem.
- Get in-depth understanding of 2SLS estimators, k-class estimators. 3SLS estimation.

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

L	T	P	Credits
0	0	4	2

Learning outcomes:
Students will be able to

- Review the basic concepts of Analysis.
- Understand the basic concepts of Advance Analysis and Topology.
- Apply the techniques of Linear Algebra for solving problems.
- Review the concepts in Complex Analysis.

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

L	T	P	Credits
0	0	4	2

Learning outcomes:

Students will be able to

- Review the basic concepts of probability.
- Understand the basic concepts of testing and inferential statistics.
- Apply the techniques of statistics for solving problems.
- Review the concepts in Stochastic Processes.

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.

Recommended Books:

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

L	T	P	Credits
0	0	0	6

Learning outcomes:.
Upon successful completion of this course, the student will be able to:
1. Understand the aspects of the Review writing and seminar presentation.
2. Write a review of existing scientific literature with simultaneous identification of knowledge gaps.
3. Identify the predatory publications and open access publications.
4. develop an understanding for scientific research.

Evaluation Criteria:
The evaluation criteria for "Project Work" shall be as follows:

S. No.	Criteria	Marks
1.	Literature review report	80
2.	Content of presentation	30
3.	Presentation Skills	25
4.	Handling of queries	15
Total		**150**

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

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

L	T	P	Credits
4	0	0	4

Learning Outcomes: The students will be able to

- Explain estimable parametric function.
- Apply the concept of empirical distribution function.
- Understand test for randomness.
- Discuss about Rank Statistics and its limiting distribution.

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

L	T	P	Credits
4	0	0	4

Learning Outcomes: The students will be able to

- Explain deterministic and stochastic processes.
- Apply the concept of random number generation.
- Understand Monte Carlo integration.
- Discuss about variance reduction techniques.

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:

2. G. Gordon, *System Simulation*, Prentice Hall of India, New Delhi, 2001.
3. 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.
4. R. Y. Rubinstein, *Simulation and Monte Carlo Method*, John Wiley & Sons, 1981.
5. T. T. Julius and R. C. Gonzalesz, *Pattern Recognition Principles*, Addison – Wesley Publishing Company, 1997.

Course Title: Investment Risk Analysis
Course Code: STA.576
Total Hours: 60

L	T	P	Credits
4	0	0	4

Learning Outcomes: The students will be able to

- Explain Financial investment companies.
- Evaluate VaR, risk aversion and capital allocation of risky assets.
- Understand pricing models.
- Discuss about Dynamic programming algorithm.

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

L	T	P	Credits
4	0	0	4

Learning Outcomes: The students will be able to

- Explain various types of censoring.
- Classify between various ageing classes and their properties.
- Understand various estimator of survival function.
- Discuss about two-sample problem.

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

L	T	P	Credits
0	0	2	1

Learning outcomes:
The students will be able to

- Learn the basic procedure for installation of the LaTeX.
- Use of LaTeX in scientific documentation.
- Understand the concept of usage of various packages.
- Develop skill of writing reports, books and articles using LaTeX.

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.