

**Central University of Punjab, Bathinda**



**Course Scheme & Syllabus**

**for**

**M.Sc. Statistics**

**I - IV SEMESTER**

## Scheme of Programme M.Sc. Statistics

### SEMESTER I

Sr. No.	Course Code	Course Title	L	T	P	Cr
1.	STA.506	Probability and Distribution Theory	4			4
2.	MAT.506	Real Analysis	4			4
3.	STA.507	Statistical Methods with Packages	3	-	-	3
4.	STA.508	Statistical Methods with Packages (Practical)	-	-	2	1
5.	MAT.508	Linear Algebra	4	-	-	4
6.	STA.509	Demography and Vital Statistics	4			4
7.	XYZ	Inter-Disciplinary Elective - 1 (From Other Departments)	2	-	-	2
8.	MAT.503	Basics of Latex	-	-	<b>2</b>	1
9.	STA.510	Basic Statistics	2	-	-	2
			<b>22</b>	-	<b>2</b>	<b>23</b>

$C_A$ : Continuous Assessment: Based on Objective Type Tests (10%) / Assignments (5%)/Term Paper (10%)

$M_1$ : Mid-Term Test-1: Based on Subjective Type Questions (25%)

$M_2$ : Mid-Term Test-2: Based on Subjective Type Questions (25%)

$E_T$ : End-Term Exam (Final): Based on Objective Type Questions (25%)

$T_M$ : Total Marks

C: Core; E: Elective; F: Foundation; VAC: Value Added Course, L: Lectures; T: Tutorial; P: Practical; Cr: Credits.  $I_E$ : Interdisciplinary elective

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

**Scheme of Programme M.Sc. Statistics**  
**SEMESTER II**

S.No	Course Code	Course Title	L	T	P	Cr
1.	MAT.521	Computer Fundamentals and C programming	3	0	0	3
2.	MAT.522	Computer Fundamentals and C programming (Practical)		0	2	1
3.	STA.521	Statistical Inference-I	3	-	-	3
4.	STA.522	Statistical Inference-I (Practical)	-	-	2	1
5.	STA.523	Sampling Theory	3	-	-	3
6.	STA.524	Sampling Theory (Practical)		-	2	1
7.	STA.525	Stochastic Processes	4	-	-	4
8.	MAT.526	Complex Analysis	4	-	-	4
9.	STA.526	Linear Models and Regression	2	-	-	2
10.	XYZ	Inter-disciplinary (From Other Departments)	2	-	-	2
11.	STA.527	Basics of Inferential Statistics	2	-	-	2
			<b>21</b>	<b>-</b>	<b>6</b>	<b>24</b>

$C_A$ : Continuous Assessment: Based on Objective Type Tests (10%) / Assignments (5%)/Term Paper (10%)

$M_1$ : Mid-Term Test-1: Based on Subjective Type Questions (25%)

$M_2$ : Mid-Term Test-2: Based on Subjective Type Questions (25%)

$E_T$ : End-Term Exam (Final): Based on Objective Type Questions (25%)

$T_M$ : Total Marks; C: Core; E: Elective; F: Foundation; L: Lectures; T: Tutorial; P: Practical; Cr: Credits.  $I_E$ : Interdisciplinary elective

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

**Scheme of Programme M.Sc. Statistics**  
**SEMESTER III**

S.No	Course Code	Course Title	L	T	P	Cr
1.	MAT.560	Research Methodology	4	-	-	4
2.	STA.551	Multivariate Analysis	3	-	-	3
3.	STA.552	Multivariate Analysis (Practical)	-	-	2	1
4.	STA.553	Design and Analysis of Experiment	3	-	-	3
5.	STA.554	Design and Analysis of Experiment (Practical)	-	-	2	1
6.	STA.555	Quality Control and Time Series	3	-	-	3
7.	STA.556	Quality Control and Time Series (Practical)	-	-	2	1
8.	STA.557	Operations Research	4	-	-	4
9.	STA.543	Seminar	-	-	-	1
10.	STA.558	Actuarial Statistics	4	-	-	4
	STA.559	Reliability Theory				
	MAT.553	Numerical Analysis	3*	-	-	3
	MAT.554	Numerical Analysis (Practical)*	-	-	2	1
	STA.560	Non-parametric Inference	4	-	-	4
	STA.561	Survival Analysis				
			<b>19</b>	<b>-</b>	<b>8</b>	<b>25</b>

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$M_2$ : Mid-Term Test-2: Based on Subjective Type Questions (25%)

$E_T$ : End-Term Exam (Final): Based on Objective Type Questions (25%)

$T_M$ : Total Marks

C: Core; E: Elective; F: Foundation; L: Lectures; T: Tutorial; P: Practical; Cr: Credits.  $I_E$ : Interdisciplinary elective

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

## Scheme of Programme M.Sc. Statistics

### SEMESTER IV

S.No	Course Code	Course Title	L	T	P	Cr
1	STA.571	Statistical Inference-II	3	-	-	3
2	STA.572	Statistical Inference-II(Practical)	-	-	2	1
3	STA.599	Project Work	-	-	12	6
4	STA.544	Seminar-II	-	-	-	1
5	STA.573	Game Theory and Non-linear Programming	4	-	-	4
	STA.574	Statistical Simulation				
	MAT.574	Advanced Numerical Analysis				
	STA.575	Econometrics				
	STA.576	Investment Risk Analysis				
	STA.577	Economic Statistics				
6	MAT.578	Fundamentals of Analysis and Linear Algebra	-	-	4	2
7	STA.578	Fundamentals of Statistics	-	-	4	2
8	XYZ	Value added course	<b>1</b>	-	-	1
			<b>8</b>	-	<b>22</b>	<b>20</b>

$C_A$ : Continuous Assessment: Based on Objective Type Tests (10%) / Assignments (5%)/Term Paper (10%)

$M_1$ : Mid-Term Test-1: Based on Subjective Type Questions (25%)

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$E_T$ : End-Term Exam (Final): Based on Objective Type Questions (25%)

$T_M$ : Total Marks

C: Core; E: Elective; F: Foundation; L: Lectures; T: Tutorial; P: Practical; Cr: Credits.  $I_E$ : Interdisciplinary elective

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

## Semester I

**Course Title: Probability and Distribution Theory**

**Course Code: STA.506**

**Total Hours: 60**

L	T	P	Cr	Marks
4	0	0	4	100

### **Objectives**

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**

Bernoulli trials, random variables (discrete and continuous). 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 and their joint, marginal and conditional p.m.f.s. and p.d.f.s, 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. Probability Integral transformation, order statistics and their distributions (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).

**Recommended Books**

1. V. K. Rohtagi and A. K. M. E. Saleh, *An Introduction to Probability Theory and Mathematical Statistics*, Wiley Eastern, 2010.
2. I. Miller and M. Miller, *Mathematical Statistics*, 6<sup>th</sup> Edition, Oxford & IBH Pub., 1999.
3. S. M. Ross, *Introduction to Probability Models*, 11<sup>th</sup> Edition, 2014.

**Suggested Readings**

1. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley International Student Edition, 1988.
2. P. Billingsley, *Probability and Measure*, 4<sup>th</sup> Edition, John Wiley & Sons, 2012.

IQAC

**Course Title: Real Analysis**

**Course Code: MAT.506**

**Total Lectures: 60**

L	T	P	Cr	Marks
4	0	0	4	100

**Objective:** 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  $\mathbb{R}^k$ , Bolzano Weierstrass theorem, Heine Borel theorem, Perfect sets, Cantor set, Separated sets, Connected sets in a metric space, Connected subsets of real line.

**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.



**Recommended Books**

1. Walter Rudin, *Principles of Mathematical Analysis*, 3rd Edition, McGraw Hill, Kogakusha, International student Edition, 1976.
2. S. C. Malik and S. Arora, *Mathematical Analysis*, New Age International Ltd., UK, 2017.

**Suggested Readings**

1. E. C. Titchmarsh, *The Theory of functions*, Oxford University Press, Oxford, 2002.
2. Tom M. Apostol, *Mathematical Analysis*, Addition –Wesley, USA, 1981.
3. Ajit Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, Narosa, Publishing House, New Delhi, 2014.
4. R. G. Bartle, *The Elements of Real Analysis*, John Willey and Sons, New York, 1976.

IQAC

**Course Title: Statistical Methods with Packages**  
**Course Code: STA.507**  
**Total Hours: 45**

L	T	P	Cr	Marks
3	0	0	3	75

### **Objectives**

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. Data on two 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**

Normal, Chi-square, t and F distributions and their relations. Population, random sample, parameter, statistic and sampling distribution. Sample mean and sample variance associated with a random sample from a normal distribution: their independence, sampling distributions, expectations and 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. Chi-square test of goodness of fit and independence of attributes. Test of significance for correlation coefficient (one and two sample problem).

### **Unit IV**

**10 hours**

**Non-parametric location tests:** One sample problem: Sign test, signed rank test, Kolmogorov-Smirnov test, Test of independence (Run test). **Two sample problem:** Wilcoxon-Mann-Whitney test, Median test, Kolmogorov-Smirnov test.

**Recommended Books**

1. A. M. Goon, M. K. Gupta and B. Dasgupta, *Fundamentals of Statistics*, Vol I and II, 2005.
2. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences*, 10<sup>th</sup> Edition, Wiley & Sons, 2013.

**Suggested Readings:**

1. F. D. Gibbons, *Non-parametric Statistical Inference*, Mc Graw Hill Inc, 1971.
2. R. V. Hogg, J. McKean and A. Craig, *Introduction to Mathematical Statistics*, 7<sup>th</sup> Edition, Pearson, 2012.

IQAC

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

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>	<b>Marks</b>
0	0	2	1	25

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

IQAC

**Course Title:** Linear Algebra

**Course Code:** MAT.508

**Total Hours:** 60

L	T	P	Cr	Marks
4	0	0	4	100

**Objective:**

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 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.

**Recommended Books**

1. K. Hoffman and R. Kunze: *Linear Algebra*, 2<sup>nd</sup> Edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2004.
2. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory*, Cengage Learning, 2004.

**Suggested Readings**

1. I. N. Herstein, *Topics in Algebra*, 2<sup>nd</sup> Edition, Wiley Eastern Limited, New Delhi, 2006.
2. P. B. Bhattacharya, S.K. Jain and S.R. Nagpaul, *First Course in Linear Algebra*, Wiley Eastern, Delhi, 2003.

IQAC

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

L	T	P	Cr	Marks
4	0	0	4	100

### **Objectives**

The course on Demography and Vital Statistics is framed to equip the students of M.Sc. Statistics with knowledge of terms and analysis of data related with vital events.

### **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.

### **Recommended Books**

1. N. Keyfitz, J. A. Beckman, *Demography through Problems*, S-Verlag New York, 1984.
2. D. I. Bartholomew, *Stochastic Models for Social Process*, John Wiley, 1982.
3. P. R. Cox, *Demography*, Cambridge University press, 1970.

### **Suggested Readings**

1. N. Keyfitz, *Applied Mathematical Demography*, Springer Verlag, 1977.
2. M. Spiegelman, *Introduction to Demography Analysis*, Harvard University press, 1969.

3. R. Ramkumar, *Technical Demography*, New Age International, 1986.
4. S. Biswas, *Stochastic Process in Demography and Applications*, Wiley Eastern Ltd., New Delhi, 1988.

IQAC



**Course Title: Basics of LaTeX**

**Course Code: MAT.503**

**Total Hours: 30**

L	T	P	Cre	Marks
1	0	0	1	25

### **Objectives**

The main objective of this course is provide a basic knowledge of LaTeX and its various applications in teaching and research.

### **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.

### **Recommended Books**

1. L. Lamport. LATEX: A Document Preparation System, User's Guide and Reference Manual. 2<sup>nd</sup> Edition, Addison Wesley, New York, 1994.
2. D. F. Griffiths and D. J. Higham, *Learning LaTeX, 2<sup>nd</sup> Edition*, Philadelphia, Pennsylvania, SIAM, 1997.

### **Suggested Readings**

1. M. Goossens, F. M. Michel, and S. Alexander, *The LaTeX companion*, 2<sup>nd</sup> Edition, Addison-Wesley, 1994.

**Course Title: Basic Statistics**

**Course Code: STA.510**

**Total Hours: 30**

L	T	P	Cr	Marks
2	0	0	2	50

**Objectives**

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. 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.

**Recommended Books**

3. P. L. Meyer, *Introductory Probability and Statistical Applications*, Oxford & IBH Pub, 1975.
4. R. V. Hogg, J. Mckean and A. Craig, *Introduction to Mathematical Statistics*, Macmillan Pub. Co. Inc., 1978.

**Suggested Readings**

2. F. E. Croxton and D. J. Cowden, *Applied General Statistics*, 1975.
3. P. G. Hoel, *Introduction to Mathematical Statistics*, 1997.

## Semester II

**Course Title: Computer Fundamentals and C Programming**

**Course Code: MAT.521**

**Total Hours: 45**

L	T	P	Cr	Marks
3	0	0	3	75

**Objectives:** 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.

### **Recommended Books:**

1. P. Norton, *Introduction to Computers*, Tata McGraw Hill, 2008.
2. B. W. Kerninghan and Ritchie D.M., *The C Programming Language*, 2<sup>nd</sup> Edition, PHI, New Delhi, 2011.

**Suggested Readings:**

1. Y. Kanetkar , *Let Us C*, 13<sup>th</sup> Edition, BPB Publications, 2013.
2. V. Rajaraman, *Fundamentals of Computers*, PHI, 2004.
3. G.B. Shelly, T.J. Cashman and M.E. Vermaat, *Introduction to Computers*, Cengage India Pvt Ltd, 2008.

IQAC

**Course Title: Computer Fundamentals and C  
Programming (Practical)  
Course Code: MAT.522**

<b>L</b>	<b>T</b>	<b>P</b>	<b>Credits</b>	<b>Marks</b>
0	0	2	1	25

**Total Hours: 30**

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

IQAC

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

L	T	P	Cr	Marks
3	0	0	3	75

### **Objectives**

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, Minimax estimator, MCMC method and Gibbs sampling.

### **Recommended Books**

1. A. K. M. E. Saleh and V. K. Rohatgi, *An Introduction to Probability and Statistics*, 2<sup>nd</sup> Edition, Wiley, 2008.
2. G. Casella and R. L. Berger, *Statistical Inference*, 2<sup>nd</sup> Edition, Duxbury Thomson Learning, 2008.
3. C. R. Rao, *Linear Statistical Inference and its Applications*, 2<sup>nd</sup> Edition, Wiley, 2002.

**Suggested Readings**

1. E. L. Lehmann, *Theory of Point, Estimation*, Student Edition, John Wiley & Sons, 1986.
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.

IQAC

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

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>	<b>Marks</b>
0	0	2	1	25

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

IQAC



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

L	T	P	Cr	Marks
3	0	0	3	75

### **Objectives**

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.

### **Recommended Books**

1. W. G. Cochran, *Sampling Techniques*, John Wiley & Sons, New York, 1977.
2. P. Mukhopadhyay, *Theory and Methods of Survey Sampling*, 2<sup>nd</sup> Edition, Prentice Hall of India, 2008.
3. D. Raj and P. Chandak, *Sampling Theory*, Narosa, 1988.

### **Suggested Readings**

1. S. K. Thompson, *Sampling*, John Wiley and Sons, New York, 2002.
2. A. Chaudhuri, *Essentials of Survey Sampling*, Prentice Hall of India, 2010.
3. A. Chaudhari and H. Stenger, *Survey Sampling Theory and Methods*, 2<sup>nd</sup> Edition, Chapman and Hall, 2005.

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

L	T	P	Cr	Marks
0	0	2	1	25

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

IQAC

**Course Title: Stochastic Processes**

**Course Code: STA.525**

**Total Hours: 60**

L	T	P	Cr	Marks
4	0	0	4	100

### **Objectives**

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

### **Recommended Books**

1. J. Medhi, *Stochastic Processes*, 2<sup>nd</sup> Ed ,Wiley Eastern Ltd., 1994.
2. S. M. Ross, *Stochastic Processes*, Wiley Publications, 1996.
3. S. Karlin and H. M. Taylor, *A First Course in Stochastic Processes*, Vol. 1, Academic Press, 1975.

### **Suggested Readings**

1. N. T. Bailey, *The Elements of Stochastic Processes*, John Wiley & Sons, Inc., New York, 1965.
2. B. R. Bhat, *Stochastic Models: Analysis and Applications*, New Age International India, 2000.

**Course Title:** Complex Analysis

**Course Code:** MAT.526

**Total Lectures:** 60

L	T	P	Cr	Marks
4	0	0	4	100

**Objective:** 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, Rouché's theorem, Möbius transformations and their properties and classification, definition and examples of conformal mappings.

### **Recommended Books**

1. Theodore W. Gamelin, *Complex Analysis*. UTM, Springer-Verlag 2001.
2. L. V. Ahlfors, *Complex Analysis*, 3<sup>rd</sup> Edition, Tata McGraw-Hill, 1979.

3. S. Ponnusamy, *Foundations of Complex Analysis*, 2<sup>nd</sup> Edition, Narosa Publishing House, 2007.

**Suggested Readings**

1. W. Tutschke and H.L. Vasudeva, *An Introduction to Complex Analysis, Classical and Modern Approaches*, 1<sup>st</sup> Edition, CRC Publications, 2004.
2. R. V. Churchill & J. W. Brown, *Complex Variables and Applications*, 8<sup>th</sup> Edition, Tata McGraw-Hill, 2014.

IQAC

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

L	T	P	Cr	Marks
2	0	0	2	50

### **Objectives**

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.

### **Recommended Books**

1. C. R. Rao, *Linear Statistical Inference and its Applications*, 2<sup>nd</sup> Edition, Wiley, 2009.
2. A. Sen and M. Srivastava, *Regression Analysis: Theory, Methods, and Applications*, illustrated Edition, Springer, 2014.
3. N. R. Draper and H. Smith, *Applied Regression Analysis*, 3rd Edition, Wiley, 2014.
4. D. C. Montgomery, E. A. Peck and G. G. Vining, *Introduction to Linear Regression Analysis*, 5<sup>th</sup> Edition, Wiley, 2013.

**Suggested Readings**

1. S. Weisberg, *Applied Linear Regression*, 4<sup>th</sup> Edition, Wiley, 2013.
2. R. D. Cook and S. Weisberg, *Residual and Influence in Regression*, Chapman & Hall, 1982.
3. F. A. Graybill, *An Introduction to Linear Statistical Models*, Vol. 1, McGraw-Hill Book, 1961.

IQAC

**Course Title: Basics of Inferential Statistics**

**Course Code: STA.527**

**Total Hours: 30**

L	T	P	Cr	Marks
2	0	0	2	50

### **Objectives**

The course will help students from other streams like Microbiological Sciences, Plant Sciences, Animal Sciences etc. to understand testing of hypotheses concept in an 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 Probability distributions like Binomial, Poisson and continuous distributions like Normal, F and student-t distribution.

### **Unit II**

**8 hours**

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

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

### **Unit III**

**7 hours**

**Parametric tests:** Test for parameters of Normal population (one sample and two sample problems) z-test, student's t-test, F and chi-square test and Analysis of Variance (ANOVA).

### **Unit IV**

**8 hours**

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

### **Recommended Books**

1. P. L. Meyer, *Introductory Probability and Statistical Applications*, Oxford & IBH Pub., 1975.



2. J. D. Gibbons, *Non-parametric Statistical Inference*, Mc Graw Hill Inc, 1971.
3. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences*, 10<sup>th</sup> Edition, John Wiley & Sons, 2013.

**Suggested Readings**

1. E. L. Lehmann and G. Casella, *Theory of Point, Estimation*, Student Edition, John Wiley & Sons, 1986.
2. A. M. Goon, M. K. Gupta and B. Dasgupta, *An Outline of Statistical Theory*, Vol. 2, The World Press Pvt. Ltd., Calcutta, 2003.

IQAC

### Semester III

**Course Title: Research Methodology**

**Course Code: MAT.560**

**Total Hours: 60**

L	T	P	Cr	Marks
4	0	0	4	100

#### **Objectives**

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 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.

#### **Recommended Books**

1. Kothari, C.R. and G. Garg (2014): *Research Methodology: Methods and Techniques*, 3<sup>rd</sup> ed., New Age International Pvt. Ltd. Publisher

2. Kumar, R. (2014): *Research Methodology – A Step-By-Step Guide for Beginners*, 4<sup>th</sup> ed., Sage Publications

**Suggested Readings**

1. Anderson, J. (2001): *Thesis and Assignment Writing*, 4<sup>th</sup> 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.

IQAC

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

L	T	P	Cr	Marks
3	0	0	3	75

### **Objectives**

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**

Null distribution of Hotelling's  $T^2$  Statistic. Application in tests on mean vector for one and more multivariate normal populations and also on 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 tests associated with discriminant functions, 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.

### **Recommended Books**

1. T. W. Anderson, *An Introduction to Multivariate Statistical Analysis*, 2<sup>nd</sup> Edition, Wiley, 1983.
2. N. C. Giri, *Multivariate Statistical Inference*. Academic Press, 1977.
3. A. M. Kshirsagar, *Multivariate Analysis*, Marcel Dekker, 1972.

**Suggested Readings**

1. R. A. Johnson and D. Wichern, *Applied Multivariate Statistical Analysis*, 5<sup>th</sup> Edition, Pearson, 2005.
2. W. K. Hardy and L. Simor, *Applied Multivariate Statistical Analysis*, 3<sup>rd</sup> Edition, Springer- Valag, 2012.

IQAC

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

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>	<b>Marks</b>
0	0	2	1	25

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

IQAC

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

L	T	P	Cr	Marks
3	0	0	3	75

### **Objectives**

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. Analysis of Basic Design: Asymptotic relative efficiency, Missing plot technique, Analysis of covariance for CRD and RBD.

### **Unit II**

**11 hours**

Concepts of balancing, orthogonality, connectedness and properties of C-matrix. General inter and intra block analysis of incomplete block designs.  $2^2$  and  $2^3$  factorial designs, Confounding, fractional replication and split-plot designs. 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  $s \times s$  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.

### **Recommended Books**

1. O. Kempthorne, *Design and Analysis of Experiments, 2<sup>nd</sup> Edition, Vol I-II*, Wiley, 2007.
2. D. C. Montgomery, *Design and Analysis of Experiment, 7<sup>th</sup> Edition*, John & sons, Wiley, 2008.
3. M. N. Dass and N. C. Giri, *Design and Analysis of Experiments, 2<sup>nd</sup> Edition*, Wiley, 1986.

### **Suggested Readings**

1. D. Raghavarao, *Construction and Combinatorial Problems in Design of Experiments*, Wiley, 1971.
2. M. C. Chakrabarti, *Mathematics of Design and Analysis of Experiments*, Asia Publishing House, 1970.
3. W. G. Cochran and G. M. Cox, *Design of Experiments*, 2<sup>nd</sup> Edition, John Wiley & Sons, 2003.

IQAC



**Course Title: Design and Analysis of Experiment  
(Practical)**

**Course Code: STA.554**

**Total Hours: 30**

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

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>	<b>Marks</b>
0	0	2	1	25

IQAC

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

L	T	P	Cr	Marks
3	0	0	3	75

### **Objectives**

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 chart, 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, spectral analysis of weakly stationary process. Periodogram and correlogram analysis.

### **Recommended Books**

1. S. Biswas, *Statistics of Quality Control, Sampling Inspection and Reliability*, New Age International Publishers Eastern Ltd, 1996.
2. D. C. Montgomery and L. A. Johnson, *Forecasting and Time Series Analysis*, Mc Graw Hill, New York, 1976.
3. D. C. Montgomery, *Introduction to Statistical Quality Control*, 5<sup>th</sup> Edition., John Wiley & Sons, 2005.

### **Suggested Readings**

1. P. J. Brockwell and A. Daris Richard, *Introduction to Time Series And Forecasting*, 2<sup>nd</sup> Edition. Springer-Verlag, New York, Inc. (Springer Texts in Statistics), 2002.
2. G. B. Wetherill, *Sampling Inspection and Quality Control*, Halsted Press, 1977.

IQAC

**Course Title: Quality Control and Time Series  
(Practical)**

**Course Code: STA.556**

**Total Hours: 30**

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>	<b>Marks</b>
0	0	2	1	25

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

IQAC

**Course Title:** Operations Research

**Course Code:** STA.557

**Total Hours:** 60

L	T	P	Cr	Marks
4	0	0	4	100

### **Objective**

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.

### **Recommended books**

1. H. A. Taha, *Operations Research - An Introduction*, Macmillan Publishing Company Inc., New York, 2006.

2. K. Swarup, P. K. Gupta, and M. Mohan, *Operations Research*, Sultan Chand & Sons, New Delhi, 2001.

**Suggested Readings**

1. S. M. Sinha, *Mathematical Programming, Theory and Methods*, Delhi: Elsevier, 2006.
2. N. S. Kambo, *Mathematical Programming Techniques*, Affiliated East-West Press Pvt. Ltd., 1984, Revised Edition, New Delhi, 2005.
3. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 1987.

IQAC

**Course Title: Seminar I**

**Course Code: STA.543**

**Total Hours: 30**

L	T	P	Cr	Marks
0	0	2	1	25

**Objectives:** 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.

IQAC

**Course Title: Actuarial Statistics**

**Course Code: STA.558**

**Total Hours: 60**

L	T	P	Cr	Marks
4	0	0	4	100

### **Objectives**

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 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 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.

### **Recommended Books**

1. N. L. Bowers, H. U. Gerber, J. C. Hickman, D. A. Jones and C. J. Nesbitt, *Actuarial Mathematics*, 2<sup>nd</sup> Edition, Society of Actuaries, USA, 1997.
2. S. D. Promislow, *Fundamentals of Actuarial Mathematics*, 2<sup>nd</sup> Edition, Wiley, 2011.
3. P. J. Boland, *Statistical and Probabilistic Methods in Actuarial Science*, Chapman and Hall/CRC, 2007.



### **Suggested Readings**

1. S. A. Klugman, H. H. Panjer, G. E. Willmot and G. G. Venter, *Loss Models: From Data to Decisions*. 3<sup>rd</sup> Edition, Wiley-Interscience, 2008.
2. D. S. Borowaik and A. F. Shapiro, *Financial and Actuarial Statistics: An Introduction*, Marcel Dekker Inc., New York-Basel, 2005.

IQAC

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

L	T	P	Cr	Marks
4	0	0	4	100

### **Objectives**

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.

### **Recommended Books**

1. R. E. Barlow and F. Proschan, *Statistical Theory of Reliability and Life Testing: Probability Models*, 2<sup>nd</sup> Edition, To Begin With, 1981.
2. J. F. Lawless, *Statistical Models and Methods of Life Time Data*, 2<sup>nd</sup> Edition, Wiley-Blackwell, 2002.
3. J. V. Deshpande and S. G. Purohit, *Lifetime Data: Statistical Models and Methods*, 2<sup>nd</sup> Edition, World Scientific, 2015.

### **Suggested Readings**

1. M. Shaked and J. G. Shanthikumar, *Stochastic Orders & Their Applications*, illustrated Edition, Springer Science & Business Media, 2007.

2. S. Zacks, *Introduction to Reliability Analysis: Probability Models and Statistical Method*, 1<sup>st</sup> Edition, Springer-Verlag, 2012.

IQAC

**Course Title:** Numerical Analysis

L	T	P	Cr	Marks
3	0	0	3	75

**Course Code:** MAT.553

**Total Hours:** 45

**Objective:** 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, Pade 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.

### **Recommended Books**

1. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6<sup>th</sup> Edition, New Age International, New Delhi, 2015.
2. R.L. Burden and J. D. Faires, *Numerical Analysis*, 9<sup>th</sup> Edition, Cengage Learning, 2011.

### **Suggested Readings**

1. S. S. Sastry, *Introductory Methods of Numerical Analysis*, 4<sup>th</sup> Edition, PHI, 2015.
2. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7<sup>th</sup> Edition, Pearson LPE, 2009.
3. R. S. Gupta, *Elements of Numerical Analysis*, 2<sup>nd</sup> Edition, Cambridge University Press, 2015.
4. K. Atkinson, *An Introduction to Numerical Analysis*, 2<sup>nd</sup> Edition, John Wiley & Sons, 1989.

IQAC

**Course Title:** Numerical Analysis (Practical)

**Course Code:** MAT.554

**Total Hours:** 30

L	T	P	Cr	Marks
0	0	2	1	25

**Objective:** 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.
3. 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.
9. To find the dominant eigenvalues and associated eigenvector by Rayleigh power method.
8. To integrate a function numerically using trapezoidal and Simpson's rule.
9. To solve the initial value problem using Euler method.
10. To solve the initial value problem using modified Euler's method.
11. To solve the initial value problem using 2<sup>nd</sup> and 4<sup>th</sup> order Runge-Kutta methods.

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

L	T	P	Cr	Marks
4	0	0	4	100

### **Objectives**

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. 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**

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 asymptotic relative efficiency. Tests for the c-sample problem: Kruskal-Wallis, Jonckheere- Terpstra tests. Concepts of Jackknifing, method of Quenouille for reducing bias, Bootstrap methods.

### **Recommended Books**

1. J. D. Gibbons and S. Chakraborti, *Nonparametrics Statistical Inference*, 2<sup>nd</sup> Edition, Marcel Dekker, Inc, 2003.
2. R. H. Randles and D. A. Wolfe, *Introduction to the Theory of Nonparametric Statistics*, Wiley, 1979.
3. W. W. Daniel, *Applied Nonparametric Statistics*, 2<sup>nd</sup> Edition, Duxbury, 2000.

4. L. Wasserman, *All of Nonparametric Statistics*, 1<sup>st</sup> Edition, Springer, 2005.

**Suggested Readings**

1. A. C. Davison and D. V. Hinkley, *Bootstrap Methods and their Applications*, Cambridge University Press, 1997.
2. M. L. Puri and P. K. Sen, *Nonparametric Methods in Multivariate Analysis*, John Wiley and Sons, 1971.

IQAC



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

L	T	P	Cr	Marks
4	0	0	4	100

**Objectives**

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.

**Recommended Books**

1. D. R. Cox and D. Oakes, *Analysis of Survival Data*, Chapters 1-4, Taylor and Francis, 1984.
2. M. J. Crowder, *Classical Competing Risks*, Chapman & Hall, CRC, London, 2001.
3. R. G. Miller, *Survival Analysis*, 2<sup>nd</sup> Edition, Wiley Inter-science, 1998.
4. J. V. Deshpande and S. G. Purohit, *Lifetime Data: Statistical Models and Methods*, 2<sup>nd</sup> Edition, World Scientific, 2015.

**Suggested Readings**

1. A. J. Gross and V. A. Clark, *Survival Distribution- Reliability Applications in Bio-medical Sciences*, John Wiley and Sons, 1976.
2. J. D. Kalbfleisch and R. L. Prentice, *The Statistical Analysis of Failure Time Data*, John Wiley and Sons, 1980.

IQAC

## Semester IV

**Course Title: Statistical Inference –II**

**Course Code: STA.571**

**Total Hours: 45**

L	T	P	Cr	Marks
3	0	0	3	75

### **Objectives**

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-Pearson (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 test, Properties of likelihood ratio test, 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, Determination of confidence intervals based on large and small samples, Uniformly most accurate one sided confidence interval and its relation to UMP test for one sided null against one sided alternative hypotheses.

### **Recommended Books**

1. A. K. M. E. Saleh and V. K. Rohatgi, *An Introduction to Probability and Statistics*, 2<sup>nd</sup> Edition, Wiley, 2008.
2. G. Casella and R. L. Berger, *Statistical Inference*, 2<sup>nd</sup> Edition, Duxbury Thomson Learning, 2008.
3. J. D. Gibbosns and S. Chakraborty, *Nonparametric Statistical Inference*, Marcel Dekker Inc, New York, 2003.

### **Suggested Readings**

1. E. L. Lehmann, *Theory of Point, Estimation*, Student Edition, John Wiley & Sons, 1986.
2. B. K. Kale, *A First Course on Parametric Inference*, Narosa Publishing House, 1999.
2. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley International Student Edition, 1988.

IQAC

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

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>	<b>Marks</b>
0	0	2	1	25

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

IQAC

**Course Title: Project Works**  
**Course Code: STA.599**  
**Total Hours: 180**

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>	<b>Marks</b>
0	0	12	6	150

**Objective**

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.

IQAC

**Course Title: Seminar II**  
**Course Code: STA.544**  
**Total Hours: 30**

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>	<b>Marks</b>
0	0	2	1	25

**Objective:** The objective of the seminar is to develop presentation and communication skills in the students so that they can compete with the future challenges in teaching, research and applications.

IQAC

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

L	T	P	Cr	Marks
4	0	0	4	100

### **Objectives**

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 Linear Programming. Fundamental Theorem of Game Theory. Solution of  $m \times n$  games by Linear Programming Method. Solution of  $2 \times 2$  games without saddle point. Principle of dominance. Graphical solution of  $(2 \times n)$  and  $(m \times 2)$  games.

### **Unit II**

**15 hours**

Non-Linear Programming Problems (NLPP): Constrained and unconstrained, With equality Constraints, Saddle points, Kuhn-Tucker necessary and sufficient conditions of optimality. Formulation of NLPP and its Graphical Solution.

### **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.

### **Recommended Books**

1. N. S. Kambo, *Mathematical Programming, Dynamic Programming, 1984.*
2. R. Bellman, *Dynamic Programming*, Reprint edition, Dover Publications Inc, 2003.
3. K. Swarup, P. K. Gupta, and M. Mohan, *Operations Research*, Sultan Chand & Sons, New Delhi, 2001.



**Suggested Readings**

1. R. Bellman, and S. Dreyfus, *Applied Dynamic Programming*, Princeton University Press, Princeton, 2016.
2. S. D. Sharma, *Operations Research*, Kedarnath Amarnath, Meerut, 2009.
3. O. L. Mangasarian, *Nonlinear Programming*, Tata McGraw-Hill New Delhi, 1969.

IQAC

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

L	T	P	Cr	Marks
4	0	0	4	100

### **Objectives**

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, importance sampling, correlated sampling control variates, stratified sampling, antithetic variates, partition of region.

### **Recommended Books**

1. R. Y. Rubinstein, *Simulation and Monte Carlo Method*, John Wiley & Sons, 1981.
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.

### **Suggested Readings**

1. T. T. Julius and R. C. Gonzalesz, *Pattern Recognition Principles*, Addison – Wesley Publishing Company, 1997.
2. G. Gordon, *System Simulation*, Prentice Hall of India, New Delhi, 2001.

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

L	T	P	Cr	Marks
3	0	0	3	75

### **Objectives**

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. Theil's BLUS procedure. 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. Monte Carlo studies and simulation.

### **Recommended Books**

1. D. N. Gujarati, *Basic Econometrics*, 4<sup>th</sup> Edition, McGraw-Hill, 2004.
2. W. H. Greene, *Econometric Analysis*, Prentice Hall, 2003.
3. J. Johnston, *Econometric Methods*, Mc Graw Hill, 1991.

### **Suggested Readings**

1. J. Kmenta, *Elements of Econometrics*, 2<sup>nd</sup> Edition, Mac Millan, 1986.
2. A. Koutsyannis, *Theory of Econometrics*, Mc Millian, 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*, 2<sup>nd</sup> Edition, John Wiley & Sons, 1988.

IQAC

**Course Title:** Advanced Numerical Analysis

**Course Code:** MAT.574

**Total Hours:** 60

L	T	P	Cr	Marks
4	0	0	4	100

**Objectives:** 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.

### **Recommended Books**

1. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7<sup>th</sup> Edition, Pearson LPE, 2009.
2. R. S. Gupta, *Elements of Numerical Analysis*, 2<sup>nd</sup> Edition, Cambridge University Press, 2015.
3. R.L. Burden and J. D. Faires, *Numerical Analysis*, 9<sup>th</sup> Edition, Cengage Learning, 2011.

### **Suggested Readings**

1. K. Atkinson, *An Introduction to Numerical Analysis*, John Wiley & Sons, 2<sup>nd</sup> Edition, 1989.
2. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6<sup>th</sup> Edition, New Age International, New Delhi, 2015.
3. 3. S.D. Conte and Carl D. Boor, *Elementary Numerical Analysis: An Algorithmic Approach*, Tata McGraw Hill, 2005.

IQAC

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

L	T	P	Cr	Marks
4	0	0	4	100

### **Objectives**

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.

### **Recommended Books**

1. Z. Bodie, A. Kane and A. J. Marcus, *Investments*, 8<sup>th</sup> Edition, Tata McGraw Hill, 2009.
2. D. Ruppert, *Statistics and Finance*, Springer, 2004.

## **Suggested Readings**

1. M. Baxter and A. Rennie, *Financial Calculus: An Introduction to Derivative Pricing*, Cambridge University Press, 1996.
2. H. H. Panjer, *Financial Economics with Application to Investments, Insurance and Pensions*, The Actuarial Foundation , 2001.

IQAC



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

L	T	P	Cr	Marks
4	0	0	4	100

### **Objectives**

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.

### **Recommended Books**

1. J. M. Henderson and R. E. Quandt, *Microeconomic Theory- Mathematical Approach*, McGraw-Hill, 1980.
2. P. Lambert, *The Distribution and Redistribution of Income*, 3<sup>rd</sup> Edition, Manchester University Press, 2001.

### **Suggested Readings**

1. N. C. Kakwani, *Income Inequality and Poverty: Method of Estimation and Policy Applications*, illustrated Edition, Oxford University Press, 1980.
2. P. A. Samuelson and W. D. Nordhaus, *Economics*, 19<sup>th</sup> Edition, Tata McGraw-Hill, 2010.

**Course Title: Fundamentals of Analysis and Linear Algebra**

**Course Code: MAT.578**

**Total Hours: 60**

L	T	P	Cr	Marks
0	0	4	2	50

**Objectives**

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.

### **Recommended Books**

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

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

L	T	P	Cr	Marks
0	0	4	2	50

### **Objectives**

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.

#### **Recommended Books:**

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

**Course Title: Value added course**

**Course Code: XYZ**

**Total Hours: 15**

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>	<b>Marks</b>
1	0	0	1	25

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