Central University of Punjab, Bathinda

Course Scheme & Syllabus

for

M.Sc. Statistics

Syllabi Applicable for Admissions in M. Sc. (Statistics), 2017

Scheme of Programme for M.Sc. Statistics
SEMESTER I

S.No	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage				T_M
								C_A	M_1	M_2	E_T	
1	STA.506	Probability and Distribution Theory	**C**	4	-	-	4	25	25	25	25	100
2	STA.507	Real Analysis	**C**	4			4	25	25	25	25	100
3	STA.508	Statistical Methods with Packages	**C**	3	-	-	3	25	25	25	25	75
4	STA.509	Statistical Methods with Packages (LAB)	**C**	-	-	2	1	-	-	-	-	25
5	STA.510	Linear Algebra	**C**	4	-	-	4	25	25	25	25	100
6	STA.511	Actuarial Statistics	**C**	4	-	-	4	25	25	25	25	100
7	XYZ	Inter-Disciplinary Elective -1 (From Other Departments)	I_E	2	**-**	**-**	2	25	25	25	25	50
Interdisciplinary courses offered by STA Faculty (For students of other Centres)												
8	STA. 503	Basic Statistics	I_E	2	-	-	2	25	25	25	25	50
				21	**-**	**2**	**22**					550

C_A **:** Continuous Assessment: Based on Objective Type Tests/ Assignments

M_1 : Mid-Term Test-1: Based on Objective Type & Subjective Type Test

M_2 : Mid-Term Test-2: Based on Objective Type & Subjective Type Test

E_T : End-Term Exam (Final): Based on Objective Type Tests

T_M : Total Marks

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

Scheme of Programme for M.Sc. Statistics
SEMESTER II

S. No	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage				T_M
								C_A	M_1	M_2	E_T	
1	STA.521	Computer Fundamentals and C programming	**F**	3	**0**	**0**	3	25	25	25	25	50
2	STA.522	Computer Fundamentals and C programming (LAB)	**F**		0	2	1	-	-	-	-	50
3	STA.523	Estimation and testing of Hypotheses	**C**	3	-	-	3	25	25	25	25	75
4	STA. 524	Estimation and testing of Hypotheses (LAB)	**C**	-	-	2	1	-	-	-	-	25
5	STA.525	Measure Theory	**C**	4	-	-	4	25	25	25	25	100
6	STA.526	Stochastic Processes	**C**	4	-	-	4	25	25	25	25	100
7	STA.527	Complex Analysis	**C**	4	-	-	4	25	25	25	25	100
8	STA.528	Linear Models and Regression	**C**	2	-	-	2	25	25	25	25	50
	XYZ	Inter-disciplinary (From Other Departments)	I_E	2	-	-	2	25	25	25	25	50
Interdisciplinary courses offered by STA Faculty (For students of other Centres)												
9	STA.504	Basics of Inferential Statistics	I_E	**2**	**-**	**-**	2	25	25	25	25	50
				22	**-**	**4**	**24**					600

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Scheme of Programme for M.Sc. Statistics
SEMESTER III

S.No	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage				T_M
								C_A	M_1	M_2	E_T	
1.	STA.502	Research Methodology	**F**	2	-	-	2	25	25	25	25	50
2	STA.551	Multivariate Analysis	**C**	3	-	-	3	25	25	25	25	75
3	STA. 552	Multivariate Analysis (LAB)	**C**	-	-	2	1	-	-	-	-	25
4	STA.553	Sampling Theory	**C**	3	-	-	3	25	25	25	25	75
5	STA.554	Sampling Theory (LAB)	**C**	-	-	2	1	-	-	-	-	25
6	STA.555	Quality Control and Time Series	**C**	3	-	-	3	25	25	25	25	75
7	STA.556	Quality Control and Time Series (LAB)	**C**	-	-	2	1	-	-	-	-	25
8	STA.597	Seminar	**F**	-	-	4	2	-	-	-	-	50
9	STA.557	Operations Research	**E**	4	-	-	4	25	25	25	25	100
	STA.558	Demography and Vital Statistics										
	STA.559	Reliability Theory										
10	STA.560	Numerical Analysis	**E**	3*	-	-	3	25	25	25	25	75
	STA.561	Numerical Analysis (LAB) **	**E**	-	-	2*	1	-	-	-	-	25
	STA. 562	Non-parametric Inference	**E**	3*	-	-	3	25	25	25	25	75
	STA.563	Non-parametric Inference (LAB) **	**E**	-	-	2*	1	-	-	-	-	25
	STA. 564	Survival Analysis	**E**	4	-	-	4	25	25	25	25	100
				19(18*)	**-**	**10(12*)**	**24**					600

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**: STA.611 is compulsory with STA.610 and STA.613 is compulsory with STA.612.

Scheme of Programme for M.Sc. Statistics
SEMESTER IV

S. No	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage				T_M
								C_A	M_1	M_2	E_T	
1.	STA.571	Design and Analysis of Experiment	C	3	-	-	3	25	25	25	25	75
2.	STA. 572	Design and Analysis of Experiment (LAB)	C	-	-	2	1	-	-	-	-	25
3.	STA.599	Project Work	C	-	-	16	8	-	-	-	-	200
4.	STA.573	Game Theory and Non-linear Programming	E	4	-	-	4	25	25	25	25	100
	STA. 574	Statistical Simulation										
	STA. 575	Advanced Numerical Analysis										
5	STA. 576	Econometrics	E	3*	-	-	3	25	25	25		75
	STA. 577	Econometrics (LAB)**	E	-	-	2	1	-	-	-	-	25
	STA.578	Investment Risk Analysis	E	4	-	-	4	25	25	25	25	100
	STA.579	Economic Statistics										
				11(10*)	**-**	18(20*)	20					500

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E_T : <u>End-Term Exam (Final):</u> Based on Objective Type Tests

T_M : Total Marks

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

**STA.621 is compulsory with STA.620.

Semester I

Course Title: Probability and Distribution Theory	L	T	P	Credits	Marks
Course Code: STA.506	4	0	0	4	100

Total Hours: 60

Objectives:

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

Unit I **(14 Lecture 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 Lecture 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 Lecture Hours)**

Bivariate random variable and their joint, marginal and conditional p.m.fs. and p.d.fs, correlation coefficient, conditional expectation. Bivariate normal distributions. Moment generating and probability generating functions. Functions of random variables and their distributions using Jacobian of transformation and other tools. Probability Integral transformation, order statistics and their distributions (continuous case only), truncated distributions, compound distributions.

Unit IV **(14 Lecture 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). Transformation of statistics.

Recommended Books:

1. V. K. Rohtagi and A. K. M. E. Saleh, *An Introduction to Probability Theory and Mathematical Statistics*, 3rd Edition, Wiley, 2015.
2. I. Miller and M. Miller, *Mathematical Statistics*, 6th Edition, Oxford & IBH Pub., 1999.
3. S. M. Ross, *Introduction to Probability Models*, 11th Edition, Academic Press, 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*, 4th Edition, John Wiley & Sons, 2012.

Course Title: Real Analysis
Course Code: STA.507
Total Lectures: 60

L	T	P	Credits	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 Lecture Hours)**

Set Theory: Finite, countable and uncountable sets

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

Unit-II **(15 Lecture 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 Lecture 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 Lecture 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, *Mathematical Analysis*, Wiley Eastern Ltd., 2010.

Suggested Readings:

1. E. C. Titchmarsh, *The Theory of functions*, 2nd Edition, Oxford University Press 1961.
2. Tom M. Apostol, *Mathematical Analysis*, Addition –Wesley, 2002.
3. Ajit Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, Narosa, Publishing House, 2014.
4. R. G. Bartle, *The Elements of Real Analysis*, John Willey and Sons, 1976.

Course Title: Statistical Methods with Packages
Course Code: STA.508
Total Hours: 45

L	T	P	Credits	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 Lecture 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 Lecture 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. Fitting of Binomial, Poisson and Normal distribution.

Unit III **(11 Lecture 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 ($\rho = 0$, $\rho = \rho_0$) (one and two sample problem).

Unit IV **(10 Lecture Hours)**

Non-parametric location tests: One sample problem: Sign test, signed rank test, Kolmogrov-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, World Press, 2005.
2. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences*, 10th Edition, Wiley & Sons, 2013.

Suggested Readings:

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

Course Title: Statistical Methods with Packages (LAB)
Course Code: STA.509
Total Hours: 30

L	T	P	Credits	Marks
0	0	2	1	25

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

Course Title: Linear Algebra
Course Code: STA.510
Total Hours: 60

L	T	P	Credits	Marks
4	0	0	4	100

Objective:
The concepts and techniques from linear algebra are of fundamental importance in many scientific disciplines. 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 Lecture Hours)**

Vector Space: Vector spaces, Subspaces, Direct sum of subspaces, Linear dependence and independence, Basis and dimensions, Linear transformations, Algebra of linear transformations, Matrix representation of a linear transformation, Rank and nullity of a linear transformation, Invariant subspaces. Change of basis,

Unit I **(16 Lecture Hours)**

Characteristic polynomial and minimal polynomial of a linear transformation, Cayley Hamilton theorem, Eigenvalues and eigenvectors of a linear transformation, Diagonalization and triangularization of a matrix, Characteristic polynomial and minimal polynomial of block matrices. Canonical forms, Diagonal forms, Triangular forms, Jordan canonical forms, rational canonical forms, Quotient spaces.

Unit III **(15 Lecture Hours)**

Linear functional, Dual space, Dual basis, Annihilators, Bilinear forms, Symmetric bilinear forms, Sylvester's theorem, quadratic forms, Hermitian forms. Reduction and classification of quadratic forms.

Unit IV **(14 Lecture 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. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory*, Cengage Learning, 2004.
2. V. Bist and V. Sahai, *Linear Algebra*, Narosa, Delhi, 2002.

Suggested Readings:

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

Course Title: Actuarial Statistics
Course Code: STA.511
Total Hours: 60

L	T	P	Credits	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 Lecture 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 Lecture Hours)**

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

Unit III **(14 Lecture 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 Lecture 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. Calculation of various payments from life tables: principle of equivalence, net premiums, prospective and retrospective provisions/reserves.

Recommended Books:

1. 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.
2. S. D. Promislow, *Fundamentals of Actuarial Mathematics*, 3rd Edition, Wiley, 2014.
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 and G. E. Willmot , *Loss Models: Further Topics*. 4th Edition, Wiley-Interscience, 2013.
2. D. S. Borowaik and A. F. Shapiro, *Financial and Actuarial Statistics: An Introduction*, 2nd Edition, Marcel Dekker Inc., New York-Basel, 2013.

Course Title: Basic Statistics
Course Code: STA.503
Total Hours: 30

L	T	P	Credits	Marks
2	0	0	2	50

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

Unit I **(7 Lecture 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 Lecture 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 Lecture 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 Lecture 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:

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

Suggested Readings:

1. F. E. Croxton and D. J. Cowden, *Applied General Statistics*, 2nd Edition, Prentice-Hall ,1975.
2. P. G. Hoel, *Introduction to Mathematical Statistics*, 6th Edition, John Wiley & Sons, 2005.

Semester II

Course Title: Computer Fundamentals and C Programming
Course Code: STA.521

L	T	P	Credits	Marks
3	0	0	3	75

Total Hours: 45

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 Lecture 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 Lecture 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 Lecture 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 Lecture 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 D.M. Ritchie, *The C Programming Language*, 2nd Edition, PHI, New Delhi, 2011.

Suggested Readings:

1. Y. Kanetkar , *Let Us C*, 13th 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.

Course Title: Computer Fundamentals and C Programming (LAB)

Course Code: STA.522

L	T	P	Credits	Marks
0	0	2	1	25

Total Hours: 30

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

Course Title: Estimation and Testing of Hypotheses
Course Code: STA.523

L	T	P	Credits	Marks
3	0	0	3	75

Total Hours: 45

Objectives:

The concepts and techniques of estimation and testing of hypothesis are of great importance in statistics. The main objective is to introduce estimation as well as introduction to hypothesis testing in practical life.

Unit I **(10 Lecture Hours)**

Estimation: Introduction to the problem of estimation. Concepts of unbiasedness, sufficiency, consistency, efficiency, completeness.

Unbiased estimation: 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 II **(11 Lecture Hours)**

Methods of estimation: method of moments, maximum likelihood estimation, minimum chi-square method, method of scoring. Basic ideas of Bayes and Minimax estimators.

Tests of Hypotheses: Concepts of critical regions, test functions, two kinds of errors, size function, power function, level of significance. Most Powerful (MP) and Uniformly Most Powerful (UMP) tests in a class of size α tests.

Unit III **(12 Lecture Hours)**

Neyman - Pearson Lemma, MP test for simple null against simple alternative hypothesis. UMP tests for simple null hypothesis against one-sided alternatives and for one-sided null against one-sided alternatives in one parameter exponential family. Extension of these results to Pitman family when only upper or lower end depends on the parameter and to distributions with MLR property. Non-existence of UMP test for simple null against two-sided alternatives in one parameter exponential family. Likelihood Ratio Tests. Wald's SPRT with prescribed errors of two types.

Unit IV **(12 Lecture Hours)**

Interval estimation: Confidence interval, confidence level, construction of confidence intervals using pivots, shortest expected length confidence interval, uniformly most accurate one sided confidence interval and its relation to UMP test for one sided null against one sided alternative hypotheses. Tests of hypotheses and interval estimation viewed as decision problems with given loss functions.

Recommended Books:

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

Course Title: Estimation and Testing of Hypotheses (LAB)
Course Code: STA.524
Total Hours: 30

L	T	P	Credits	Marks
0	0	2	1	25

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

Course Title: Measure Theory
Course Code: STA.525
Total Hours: 60

L	T	P	Credits	Marks
4	0	0	4	100

Objective: The objective of this course is to introduce student's measure theory in an abstract setting after having studied Lebesgue measure on real line. Some important theorems are also studied.

Unit-I **(15 Lecture Hours)**

Semi-algebras, Algebras, Monotone class, σ -algebras, Measure and outer measures, Caratheödory extension process of extending a measure on semi-algebra to generated σ -algebra, Completion of a measure space.

Unit-II **(15 Lecture Hours)**

Borel sets, Lebesgue outer measure and Lebesgue measure on R, Translation invariance of Lebesgue measure, Characterizations of Lebesgue measurable sets, Countable additivity, Continuity of measure and Borel-Cantelli Lemma, Existence of a non-measurable set, Measurability of Cantor set.

Unit-III **(15 Lecture Hours)**

Measurable functions on a measure space and their properties, Borel and Lebesgue measurable functions, Simple functions and their integrals, Littlewood's three principle and Egoroff's Theorem (statement only), Lebesgue integral on R and its properties.

Unit-IV **(15 Lecture Hours)**

Bounded convergence theorem, Fatou's lemma, Lebesgue monotone convergence theorem, LeQbesgue dominated convergence theorem, L^p spaces, Young's inequality, Minkowski's and Hölder's inequalities, Riesz-Fischer theorem (statement only).

Recommended Books:

1. H.L. Royden, *Real Analysis*, Macmillan, New York, 1988.
2. G.de Bara, *Measure Theory and Integration*, Ellis Horwood Limited, England, 2003.
3. P. R. Halmos, *Measure Theory*, *Grand Text Mathematics*, 14th Edition, Springer, 1994.

Suggested Readings:

1. I. K. Rana, *An Introduction to Measure and Integration*, 2nd Edition, Narosa Publishing House, New Delhi, 2005.
2. B. Krishna and A. Lahiri, *Measure Theory*, Hindustan Book Agency, 2006.
3. Terence Tao, *An Introduction To Measure Theory*, American Mathematical Society, 2012.
4. G.B. Folland, *Real Analysis*, 2nd Edition, John Wiley, New York, 1999.

Course Title: Stochastic Processes
Course Code: STA.526
Total Hours: 60

L	T	P	Credits	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 Lecture 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 Lecture Hours)**

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

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

Unit III **(15 Lecture Hours)**

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

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

Unit IV **(15 Lecture Hours)**

Statistical Inference for Markov Chains: Estimation of transition probabilities.

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*, 3rd Edition , New Age Science Limited, 2010.
2. S. M. Ross, *Stochastic Processes,* 2nd Edition, Wiley, 1996.
3. S. Karlin and H. M. Taylor, *A First Course in Stochastic Processes*, 2nd Edition, Academic Press, 2012.

Suggested Readings:

1. N. T. Bailey, *The Elements of Stochastic Processes: With Applications to the Natural Sciences*, John Wiley & Sons, New York, 1990.
2. B. R. Bhat, *Stochastic Models: Analysis and Applications*, New Age International, 2004.

Course Title: Complex Analysis
Course Code: STA.527
Total Lectures: 60

L	T	P	Credits	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 Lecture 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 Lecture 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 Lecture 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 Lecture Hours)**

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

Recommended Books:

1. L. V. Ahlfors, *Complex Analysis*, Tata McGraw Hill, 1979.
2. S. Ponnusamy, *Foundations of Complex Analysis*, Narosa Publishing House, 2007.

Suggested Readings:

1. W. Tutschke and H. L. Vasudeva, *An Introduction to Complex Analysis: Classical and Modern Approaches*, CRC Publications, 2004.
2. R. V. Churchill & J. W. Brown, *Complex Variables and Applications*, Tata McGraw Hill, 1996.

Course Title: Linear Models and Regression
Course Code: STA.528
Total Hours: 30

L	T	P	Credits	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 Lecture Hours)**

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

Unit II **(8 Lecture 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 Lecture 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.

Unit IV **(8 Lecture 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. Analysis of variance (ANOVA*) and* analysis *of* covariance (ANCOVA).

Recommended Books:

1. C. R. Rao, *Linear Statistical Inference and its Applications*, 2nd 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, 5th Edition, Wiley, 2013.

Suggested Readings:

1. S. Weisberg, *Applied Linear Regression*, 4th 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.

Course Title: Basics of Inferential Statistics
Course Code: STA.504

L	T	P	Credits	Marks
2	0	0	2	50

Total Hours: 30

Objectives:

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

Unit I **(7 Lecture 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 Lecture 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 Lecture 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 Lecture 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.

Recommended Books:

1. P. L. Meyer, *Introductory Probability and Statistical Applications*, Oxford & IBH Pub., 1975.
2. J. D. Gibbons, *Non-parametric Statistical Inference*, McGraw-Hill Inc, 1971.
3. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences*, 10^{th} 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, 2003.

Semester III

Course Title: Research Methodology
Course Code: STA.502

L	T	P	Credits	Marks
2	0	0	2	50

Total Hours: 30

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 **(7 Lecture 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 **(8 Lecture 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 **(7 Lecture 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 **(8 Lecture 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, 3rd Edition, New Age International Pvt. Ltd. Publisher.
2. Kumar, R. (2014): *Research Methodology–A Step-By-Step Guide for Beginners*, 4th Edition, Sage Publications.

Suggested Readings:

1. Anderson, J. (2001): *Thesis and Assignment Writing*, 4th Edition, 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.

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

L	T	P	Credits	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 Lecture 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 Lecture 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 Lecture 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 Lecture 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*, 2nd Edition, Wiley India Pvt. Limited, 2009.
2. N. C. Giri, *Multivariate Statistical Inference*. Academic Press, 1977.
3. A. M. Kshirsagar, *Multivariate Analysis*, New York: Marcel Dekker, 1972.

Suggested Readings:

1. R. A. Johnson and D. Wichern, *Applied Multivariate Statistical Analysis*, 6th Edition, Pearson, 2013.
2. W. K. Hardly and L. Simor, *Applied Multivariate Statistical Analysis*, 4th Edition, Springer, 2015.

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

L	T	P	Credits	Marks
0	0	2	1	25

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

Course Title: Sampling Theory
Course Code: STA.553
Total Hours: 45

L	T	P	Credits	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 Lecture 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 Lecture 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 Lecture 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 Lecture 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*, 3rd Edition, Wiley & Sons, 2007.
2. P. Mukhopadyay, *Theory and Methods of Survey Sampling*, 2nd Edition, Prentice Hall of India, 2008.
3. D. Raj and P. Chandak, Sampling Theory, Narosa, 1988.

Suggested Readings:

1. S. K. Thompson, *Sampling*, 3rd Edition, John Wiley and Sons, 2012.
2. A. Chaudhuri, *Essentials of Survey Sampling*, Prentice Hall of India, 2010.
3. A. Chaudhari and H. Stenger, *Survey Sampling Theory and Methods*, 2nd Edition, Chapman and Hall, 2005.

Course Title: Sampling Theory (LAB)
Course Code: STA.554
Total Hours:30

L	T	P	Credits	Marks
0	0	2	1	25

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

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

L	T	P	Credits	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 Lecture 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 Lecture 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 Lecture 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, curtailed and semi-curtailed sampling plans, Dodge's continuous sampling inspection plans for inspection by variables for one-sided and two-sided specifications.

Unit IV **(11 Lecture 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*, McGraw Hill, New York, 1976.
3. D. C. Montgomery, *Introduction to Statistical Quality Control*, 6^{th} Edition, Wiley, 2009.

Suggested Readings:

1. P. J. Brockwell and A. Daris Richard, *Introduction to Time Series And Forecasting*, 3^{rd} Edition, Springer, 2016.
2. G. B. Wetherill, *Sampling Inspection and Quality Control*, 2^{nd} Edition, Springer-science and Business Media, 2013.

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

L	T	P	Credits	Marks
0	0	2	1	25

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

Course Title: Seminar
Course Code: STA.597
Total Hours: 60

L	T	P	Credits	Marks
-	-	4	2	50

Course Title: Operations Research
Course Code: STA.557

L	T	P	Credits	Marks
4	0	0	4	100

Total Hours: 60

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 **(15 Lecture Hours)**

Operations Research and its Scope, Necessity of Operations Research in industry 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 **(15 Lecture Hours)**

Duality theory, Dual linear Programming Problems, Fundamental properties of dual problems, Complementary slackness, Unbounded solution in Primal. Dual Simplex Algorithm, Sensitivity analysis.

Unit-III **(15 Lecture 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 and Sequencing.

Unit -IV **(15 Lecture Hours)**

Replacement problem, replacement of items that Deteriorate, replacement of items that fails completely. Job Sequencing Problems; Introduction and assumption, Processing of n jobs through two machines, Processing of n jobs through three machines and m machines, Processing two jobs through n machines.

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.

Course Title: Demography and Vital Statistics
Course Code: STA.558

L	T	P	Credits	Marks
4	0	0	4	100

Total Hours: 60

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 Lecture 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 Lecture 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 Lecture 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 Lecture 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 and J. A. Beckman, *Demography through Problems*, illustrated Edition, Springer Science & Business Media, 2013.
2. D. I. Bartholomew, *Stochastic Models for Social Process*, 3rd Edition, Wiley, 1982.
3. P. R. Cox, *Demography*, 5th Edition, Cambridge University press, 1978.

Suggested Readings:

1. N. Keyfitz, *Applied Mathematical Demography*, 2nd Edition, Springer Science & Business Media, 2013.
2. R. Ramkumar, *Technical Demography*, 1st Edition, New Age International, 2006.
3. S. Biswas and V. K. Sehgal, *Stochastic Process in Demography and Applications*, illustrated Edition, Wiley, 1988.

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

L	T	P	Credits	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 Lecture 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 Lecture 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 Lecture 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 Lecture 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*, 2nd Edition, To Begin With, 1981.
2. J. F. Lawless, *Statistical Models and Methods of Life Time Data*, 2nd Edition, Wiley-Blackwell , 2002.
3. J. V. Deshpande and S. G. Purohit, *Lifetime Data: Statistical Models and Methods*, 2nd 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*, 1st Edition, Springer-Verlag, 2012.

Course Title: Numerical Analysis
Course Code: STA.560

L	T	P	Credits	Marks
3	0	0	3	75

Total Hours: 45

Objective:

The aim of this course is to teach the applications of various numerical techniques for a variety of problems occurring in daily life. At the end of the course, the students will be able to do programming in C/C++/MATLAB and understand the basic concepts in Numerical Analysis of differential equations.

Unit-I **(11 Lecture 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 Lecture Hours)**

Linear Systems of Equations: Gauss Elimination, Gauss-Jordan method, LU decomposition, Gauss- Seidel iteration method.

Polynomial Interpolation: Interpolating polynomial, Lagrange and Newton divided difference interpolation, Error in interpolation, Finite difference formulas, Hermite Interpolation.

Unit-III **(11 Lecture 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 Lecture 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^{th} Edition, New Age International, New Delhi, 2015.
2. R.L. Burden and J. D. Faires, *Numerical Analysis*, 9^{th} Edition, Cengage Learning, 2011.

Suggested Readings:

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

Course Title: Numerical Analysis (Lab)
Course Code: STA.561
Total Hours: 30

L	T	P	Credits	Marks
0	0	2	1	25

Objective: Laboratory experiments will be set in context with the materials covered in theory in C/C++/MATLAB.

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 root of f(x)=0 in the detected interval.
2. To find the root of f(x)=0 using Newton-Raphson and fixed point iteration methods.
3. To compute the intermediate value using the Newton's forward difference interpolation formula.
4. To compute Lagrange and divided difference interpolating polynomials.
5. To solve linear system of equations using Gauss elimination (without pivoting) method.
6. To solve linear system of equations using Gauss- Seidel method.
7. To find the dominant eigen-value and associated eigen-vector 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 and modified Euler's methods.
10. To solve the initial value problem using and Runge-Kutta methods.

Course Title: Non-Parametric Inference
Course Code: STA.562
Total Hours: 60

L	T	P	Credits	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 Lecture 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 Lecture 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 Lecture 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 Lecture 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 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.

Recommended Books:

1. J. D. Gibbons and S. Chakraborti, *Nonparametrics Statistical Inference*, 2nd 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*, 2nd Edition, Duxbury, 2000.
4. L. Wasserman, *All of Nonparametric Statistics*, 1st 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.

Course Title: Non-Parametric Inference (LAB)
Course Code: STA.563
Total Hours: 30

L	T	P	Credits	Marks
0	0	2	1	25

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

Course Title: Survival Analysis
Course Code: STA.564
Total Hours: 60

L	T	P	Credits	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 Lecture 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 Lecture 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 Lecture 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 Lecture 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*, 2nd Edition, Wiley Inter-science, 1998.
4. J. V. Deshpande and S. G. Purohit, *Lifetime Data: Statistical Models and Methods*, 2nd 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.

Semester IV

Course Title: Design and Analysis of Experiment
Course Code: STA.571
Total Hours: 45

L	T	P	Credits	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 Lecture 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 Lecture Hours)**

Concepts of balancing, orthogonality, connectedness and properties of C-matrix.General inter and intra block analysis of incomplete block designs. 2^2, 2^3, 3^2 and 3^3 factorial designs, 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 Lecture 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 Lecture Hours)**

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

Recommended Books:

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

Suggested Readings:

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

Course Title: Design and Analysis of Experiment (LAB)
Course Code: STA.572
Total Hours: 30

L	T	P	Credits	Marks
0	0	2	1	25

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

Course Title: Project Work
Course Code: STA.599
Total Hours: 120

L	T	P	Credits	Marks
0	0	16	8	200

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

L	T	P	Credits	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 Lecture Hours)**

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

Unit II **(15 Lecture Hours)**

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

Unit III **(15 Lecture 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 Lecture Hours)**

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

Recommended Books:

1. N. S. Kambo, *Mathematical Programming, Dynamic Programming, 1984*.
2. R. Bellman, *Dynamic Programming*, Reprint edition, Dover Publications Inc, 2003.

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.

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

L	T	P	Credits	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 Lecture Hours)**

Simulation: An introduction, need of simulation, physical versus digital simulation, Buffen's needle problem. Deterministic and stochastic processes. Use of simulation in defense and inventory problems.

Unit II **(14 Lecture Hours)**

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

Unit III **(16 Lecture Hours)**

Random Variates Generation: Inverse transform 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 Lecture 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: Advanced Numerical Analysis
Course Code: STA.575

L	T	P	Credits	Marks
4	0	0	4	100

Total Hours: 60

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, Eigen value problems, Interpolation and Approximation techniques and their use in differentiation and integration, differential equations etc.

UNIT- I **(16 Lecture 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: Triangularization, Cholesky and Partition methods, SOR method with optimal relaxation parameters.

UNIT-II **(14 Lecture Hours)**

Eigen-Values of Real Symmetric Matrix: Similarity transformations, Gerschgorin's bound(s) on eigenvalues, Jacobi, Givens, Householder and Rutishauser 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 Lecture 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, Applications of cubic spline to ordinary differential equation of boundary value type.

UNIT- IV **(16 Lecture 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*, 7th Edition, Pearson LPE, 2009.
2. R. S. Gupta, *Elements of Numerical Analysis*, Cambridge University Press, 2nd Edition, 2015.
3. R.L. Burden and J. D. Faires, *Numerical Analysis*, 9th Edition, Cengage Learning, 2011.

Suggested Readings:

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

Course Title: Econometrics
Course Code: STA.576
Total Hours: 45

L	T	P	Credits	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 Lecture 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 Lecture 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 Lecture 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 Lecture 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*, 4th 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*, 2nd 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*, 2nd Edition, John Wiley & Sons, 1988.

Course Title: Econometrics (LAB)
Course Code: STA.577
Total Hours: 30

L	T	P	Credits	Marks
0	0	2	1	25

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

Course Title: Investment Risk Analysis
Course Code: STA.578
Total Hours: 60

L	T	P	Credits	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 measure to measure risk will be studied in this course.

Unit I **(15 Lecture 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 Lecture 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 Lecture 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 Lecture 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*, 10th Edition, Tata McGraw Hill, 2014.
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, 2012.
2. H. H. Panjer, *Financial Economics with Application to Investments, Insurance and Pensions*, The Actuarial Foundation , 2001.

Course Title: Economic Statistics
Course Code: STA.579
Total Hours: 60

L	T	P	Credits	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 Lecture Hours)**

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

Unit II **(15 Lecture 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 Lecture 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 Lecture 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,* 3rd 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*, 19th Edition, Tata McGraw-Hill, 2010.