Central University of Punjab, Bathinda

Course Scheme & Syllabus

for

M.Sc. Statistics

Syllabi Applicable for Admissions in M. Sc. (Statistics), 2015

Scheme of Programme M.Sc. Statistics
SEMESTER I

S. No.	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage C_A	M_1	M_2	E_T	T_M
1	STA.401	Research Methodology-I	F	2	-	-	2	25	25	25	20	50
2	STA.501	Probability and Distribution Theory	C	4	-	-	4	25	25	25	25	100
3	STA.502	Statistical Methods with Packages	C	3	-	-	3	25	25	25	25	75
4	STA.503	Statistical Methods with Packages (LAB)	C	-	-	2	1	-	-	-	-	25
5.	STA.504	Sampling Theory	C	3	-	-	3	25	25	25	25	75
6.	STA.505	Sampling Theory (LAB)	C	-	-	2	1	-	-	-	-	25
7.	STA.506	Statistical Methods and Fortran	C	3	-	-	3	25	25	25	25	75
8.	STA.507	Statistical Methods and Fortran (LAB)	C	-	-	2	1	-	-	-	-	25
9	STA.508	Linear Algebra	E									
	STA.509	Analysis		4	-	-	4	25	25	25	25	100
10		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)												
11	STA.402	Basic Statistics	I_E	2	-	-	2	25	25	25	25	50
				21	**-**	**6**	**24**					600

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 M.Sc Statistics
SEMESTER II

S. No.	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage C_A	M_1	M_2	E_T	T_M
1	STA. 403	Computational Methods	F	2	**0**	**0**	2	25	25	25	25	50
2	STA.404	Computational Methods (LAB)	F	0	0	4	2	-	-	-	-	50
3	STA.510	Linear Models and Regression	C	2	-	-	2	25	25	25	25	50
4	STA.511	Estimation and Testing of Hypothesis	C	3	-	-	3	25	25	25	25	75
5	STA.512	Estimation and Testing of Hypothesis (LAB)	C	-	-	2	1	-	-	-	-	25
6.	STA.513	Mathematical Programming	E									
7.	STA.514	Actuarial Statistics		4	-	-	4	25	25	25	25	100
8.	STA.515	Fundamental of Computer Science and Programming In C and C++	E	3	-	-	3	25	25	25	25	75
9.	STA.516	Fundamental of Computer Science and Programming In C and C++(LAB)		-	-	2	1	-	-	-	-	25
10.	STA.517	Demography and vital Statistics		4	-	-	4	25	25	25	25	100
11	STA.518	Reliability Theory	E									
12	STA.519	Statistical Simulation		4	-	-	4	25	25	25	25	100
13	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)												
14	STA.405	Basics of Inferential Statistics	I_E	**2**	**-**	-	2	25	25	25	25	50
				21	**-**	**6**	**24**					600

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Scheme of Programme M.Sc Statistics

SEMESTER III

S. No.	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage C_A	M_1	M_2	E_T	T_M
1.	STA.406	Research Methodology II	F	2	-	-	2	25	25	25	25	50
2.	STA.601	Numerical Analysis	C	3	-	-	3	25	25	25	25	75
3	STA.602	Numerical Analysis (LAB)	C	-	-	2	1	-	-	-	-	25
4	STA.603	Measure Theory	C	4	-	-	4	25	25	25	25	100
3	STA.604	Quality Control and Time Series	C	3	-	-	3	25	25	25	25	75
4	STA.605	Quality Control and Time Series (LAB)	C	-	-	2	1	-	-	-	-	25
5.	STA.606	Econometrics	C	3	-	-	3	25	25	25	25	75
6.	STA.607	Econometrics (LAB)	C	-	-	2	1	-	-	-	-	25
7	STA.608	Stochastic processes	C	4	-	-	4	25	25	25	25	100
8	STA.599	Seminar	F	-	-	4	2	-	-	-	-	50
				19	-	**10**	**24**					600

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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 M.Sc Statistics

SEMESTER IV

S.No	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage C_A	M_1	M_2	E_T	T_M
1	STA.609	Multivariate Analysis	C	3	-	-	3	25	25	25	25	75
2	STA.610	Multivariate Analysis (LAB)	C	-	-	2	1	-	-	-	-	25
3.	STA.611	Design and Analysis of Experiment	C	3	-	-	3	25	25	25	25	75
4.	STA.612	Design and Analysis of Experiment (LAB)	C	-	-	2	1	-	-	-	-	25
5.	STA.600	Dissertation Research	C	-	-	16	8	-	-	-	-	200
6	STA.613 STA.614 STA.615	Advanced Numerical Analysis Game Theory and Non Linear Programming Non-parametric Inference	E	4	-	-	4	25	25	25	25	100
7	STA.616 STA.617 STA.618	Investment Risk Analysis Economic Statistics Queueing Theory and Advanced Stochastic Processes	E	4	-	-	4	25	25	25	25	100
				14	-	20	24					600

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

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Semester I

Course Title: Research Methodology-I
Course Code: STA.401

L	T	P	Credits	Marks
2	0	0	2	50

Total Hours: 32
Objectives:

The course Research Methodology - General has been framed to introduce basic concepts of Research Methods. The course covers preparation of research plan, reading and understanding of scientific papers, scientific writing, research proposal writing, ethics, plagiarism, laboratory safety issues etc.

Unit I **(8 Lecture Hours)**

Introduction: Meaning and importance of research, Different types and styles of research, Role of serendipity, Critical thinking, Creativity and innovation, Hypothesis formulation and development of research plan, Art of reading, understanding and writing scientific papers, Literature survey, Interpretation of results and discussion, Poster preparation and presentation.

Unit II **(8 Lecture Hours)**

Library: Classification systems, e-Library, Reference management, Web-based literature search engines, Intellectual property rights (IPRs). Entrepreneurship and Business Development: Importance of entrepreneurship and its relevance in career growth, Types of enterprises and ownership.

Unit III **(8 Lecture Hours)**

Good Laboratory Practices: Recent updates on good laboratory practices. Laboratory Safety Issues: Lab, Workshop, Electrical, Health and fire safety, Safe disposal of hazardous materials.

Unit IV **(8 Lecture Hours)**

Intellectual Property Rights: Intellectual Property, intellectual property protection (IPP) and Intellectual property rights (IPR), WTO (Word Trade Organization), WIPO (Word Intellectual property organization. GATT (General Agreement on Traffic and Trade), TRIPs (Trade Related Intellectual Property Rights), TRIMS (Trade Related Investment Measures) and GATS (General Agreement on Trades in Services), Nuts and Bolts of Patenting, Ethics and Values in IP.

Recommended Books:

1. S. Gupta, *Research Methodology and Statistical techniques*, Deep and Deep Publications (P) Ltd. New Delhi, India, 2005.

2. C. R. Kothari, *Research Methodology*, New Age International, New Delhi, India, 2008.

3. **Web resources:** www.sciencedirect.com for journal references, www.aip.org and www.aps.org for reference styles.

4. **Web resources:** www.nature.com, www.sciencemag.org, www.springer.com, www.pnas.org, www.tandf.co.uk, www.opticsinfobase.org for research updates.

Course Title: Probability and Distribution Theory
Course Code: STA.501
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

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 **(13 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 **(14 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, Chi-square, 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 and multinomial 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, Chebyshev, Holder, Jensen and Liapunov inequalities. Convergence in probability and in distribution, week 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. P. L. Meyer, *Introductory Probability and Statistical Applications*, Oxford & IBH Pub., 1975.
2. I. Miller and M. Miller, *Mathematical Statistics,* Sixth edition, Oxford & IBH Pub., 1999.
3. C. R. Rao, *Linear Statistical Inference and its Applications*, 2nd Edition, Wiley Eastern, 2002.
4. S. Johnson and S. Kotz, *Distributions in Statistics*, Vol. I, II and III, Houghton and Miffin, 1972.

Course Title: Statistical Methods with Packages
Course Code: STA.502
Total Hours: 45

L	T	P	Credits	Marks
3	0	0	3	75

Objectives:
The course is designed to equip the students with various technique used in summarization and analysis of data and also to give understanding of 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 **(10 Lecture Hours)**

Order Statistics: Discrete and continuous joint and marginal distributions of order statistics, distribution of range. Distribution of censored sample. Examples based on continuous distributions.

Unit III **(11 Lecture Hours)**

Confidence intervals for distribution quantiles, tolerance limits for distributions. Asymptotic distribution of function of sample moments. U-Statistics.

Unit IV **(13 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, Kolmogrov-Smirnov test, Run test. Non-parametric scale tests: Ansari-Bradley test, Mood test, Kendall's Tau test, test of randomness, consistency of tests and ARE.

Recommended Books:

1. F. D. Gibbons, *Non-parametric Statistical Inference*, Mc Graw Hill Inc, 1971.
2. R. V. Hogg, and A. T. Craig, *Introduction to Mathematical Statistics*, Macmillan Pub. Co. Inc., 1978.
3. F. E. Croxton and D. J. Cowden, *Applied General Statistics*, 1975.
4. P. G. Hoel, *Introduction to Mathematical Statistics*, 1997.

Course Title: Statistical Methods with Packages (LAB)
Course Code: STA.503
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: Sampling Theory
Course Code: STA.504
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)**

Basic ideas and distinctive features of sampling; Probability sampling designs, sampling schemes, inclusion probabilities and estimation; Review of important results in simple and stratified random sampling.

Unit II **(12 Lecture Hours)**

Sampling with varying probabilities (unequal probability sampling): PPSWR /WOR methods [cumulative total and Lahiri's scheme] and related estimators of a finite population total or mean (Hansen – Hurwitz and Des Raj estimators for a general sample size and Murthy's estimator for a sample of size 2). Horvitz – Thompson Estimator (HTE) of a finite population total /mean. Non-negative variance estimation. Ratio and Regression Estimators.

Unit III **(12 Lecture Hours)**

Double (two-phase) sampling with special reference to the selection with unequal probabilities in at least one of the phases; Double sampling for ratio and regression estimators of population mean, systematic sampling and its application to structured populations; Cluster sampling- equal clusters; Two-stage sampling with equal size of first stage units.

Unit IV **(10 Lecture Hours)**

Non-sampling error with special reference to non-response problems.

Recommended Books:

1. A. Chaudhuri, *Essentials of Survey Sampling*, Prentice Hall of India, 2010.
2. A. Chaudhari, and H. Stenger, *Survey Sampling Theory and Methods,* 2nd Edition, Chapman and Hall, 2005.
3. W. G. Cochran, *Sampling Techniques*, John Wiley & Sons, New York, 1977.
4. A. S. Hedayat, and B. K. Sinha, *Design and Inference in Finite Population Sampling*, Wiley, New York, 1991.
5 P. S. Levy and S. Lemeshow, *Sampling of Populations-Methods and Applications*, Wiley, 2008.
6. Steven K. Thompson, *Sampling*, John Wiley and Sons, New York, 2002.

Course Title: Sampling Theory (LAB)
Course Code: STA.505
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: Statistical Computing using FORTRAN
Course Code: STA.506
Total Hours: 38

L	T	P	Credits	Marks
3	0	0	3	75

Objectives:
The course is designed to equip the students with basic knowledge of computer and to develop programming skills and understanding of FORTRAN language.

Unit I **(9 Lecture Hours)**

Introduction to Computers: Binary numbers, ASCII, floating point notation, Central Processing Unit, Microprocessor, Memory, Data storage devices, Input and Output devices, Computer based communication techniques.

Unit II **(9 Lecture Hours)**

Introduction to Software: system software, Programming Languages, Program development: Defining the problem, Top-Down Design. Structured Design, developing an algorithm, flow chart, Testing and debugging the program.

Unit III **(10 Lecture Hours)**

Programming Language - I: History of Fortran, Introduction to Fortran 95, Language elements, Character set, Tokens, Source Form, Concept of type, Literal constants of intrinsic type, names scalar variables of intrinsic type, derived data type, arrays of intrinsic type, character substrings, objects and sub objects, pointers.

Unit IV **(10 Lecture Hours)**

Programming Language -II: Scalar numeric expressions and assignment, scalar relational operators, scalar logical expressions and assignments, scalar character expression and assignment. Structure constructors and scalar defined operators, scalar defined assignments, array expression, array assignments, pointers in expressions and assignments.

Recommended Books:

1. M. W. Meyer, Baber, R.L. and Pfaffenberger, B., *Computers in your Future*, Prentice Hall of India, 1999.
2. M. Metcalf and J. Reid, *FORTRAN 90195 Explained*, Oxford University Press, 2000.
3. S. J. Chapman, *Introduction to FORTRAN 90-95*, Tata McGraw Hill Publishing Company, 1999.

Course Title: Statistical Computing using Fortran (LAB)
Course Code: STA.507
Total Hours: 30

L	T	P	Credits	Marks
0	0	2	1	25

Control Constructs: The *go to* statement, the *if* statement and construct, the *case* and *do* constructs.
Input/output: Input/output statements, format definition, unit numbers, internal files, formatted input, formatted output, list directed I/O, carriage control, edit descriptors, unformatted I/O, data file and its processing.
Arrays Features and Specification Statements: zero-sized, arrays, assumed- shape arrays, automatic objects; *allocate*, *deallocate* and *specify* statements; elemental operations, *where* and *for all* statements and constructs, array elements, array objects and assignments, arrays of pointers, pointer as aliases, array constructors.
Specification Statements: Declaring entities of different shapes, initial values for variables, public and private attributes.
Program Units and Procedures: Main program, external subprogram, internal subprograms, modules, arguments of procedures, function subprogram, subroutine subprogram, explicit and implicit interfaces, procedure as arguments.
SPSS: Introduction, data files, data editor, data transfer, file handling, pivot tables, command syntax rules.

Course Title: Linear Algebra
Course Code: STA.508
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

Objectives:
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 **(14 Lecture Hours)**

Vector Space: vector spaces, subspaces, direct sum of subspaces, linear dependence and independence, basis and dimensions, linear transformations, quotient spaces, algebra of linear transformations, linear functions, dual spaces, matrix representation of a linear transformation, rank and nullity of a linear transformation, invariant subspaces.

Unit II **(15 Lecture Hours)**

Characteristic polynomial and minimal polynomial of a linear transformation, eigenvalues and eigenvectors of a linear transformation, diagonalization and triangularization of a matrix, Cayley Hamilton Theorem, Matrix representation of Linear Transformation, Change of Basis, Canonical forms, Diagonal forms, triangular forms, Jordan Canonical Forms.

Unit III **(14 Lecture Hours)**

Bilinear forms, symmetric bilinear forms, Sylvester’s theorem, quadratic forms, Hermitian forms. Inner product spaces. Norms and Distances, Orthonormal basis, Orthogonality, Schwartz inequality, The Gram-Schmidt Orthogonalization process,

Unit IV **(13 Lecture Hours)**

The Adjoint of a Linear operator on an inner product space, Normal and self-Adjoint Operators, Unitary and Normal Operators, Bilinear and Quadratic forms, reduction and classification of quadratic forms.

Recommended Books:

1. P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, *First Course in Linear Algebra*, Wiley Eastern , Delhi, 1991.
2. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory*, Academic Press, 2004.
3. I. N. Herstein, *Topics in Algebra*, Delhi Vikas, 1998.
4. V. Bist and V. Sahai, *Linear Algebra*, Narosa, Delhi, 2002.
5. K. Hoffman and R. Kunze, *Linear Algebra*, 2nd edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2004.

Course Title: Analysis
Course Code: STA.509
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

Objectives:

The aim of this course is to make the students learn fundamental concepts of metric spaces, The Riemann-Stieltjes integral as a generalization of Riemann Integral, the calculus of several variables and basic theorem.

Unit I **(15 Lecture Hours)**

Elementary set theory: Real number system as a complete ordered field, Archimedean property, supremum, infimum. Sequences and series, convergence, uniform convergence, Continuity, uniform continuity, differentiability, mean value theorem. 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 R^{k}, Perfect sets, Cantor set, Separated sets, connected sets in a metric space, connected subsets of real line.

Unit II **(14 Lecture Hours)**

Convergent sequences (in Metric spaces), Cauchy sequences, subsequences, Complete metric space, Examples of complete metric space, Limits of functions (in Metric spaces), Continuous functions, continuity and compactness, Continuity and connectedness. Separable Metric spaces. Cantor's intersection theorem, category of a set and Baire's category theorem, Banach contraction principle.

Unit III **(13 Lecture Hours)**

Functions of several variables, linear transformation, Derivatives is an open subject, Chain rule, Partial derivatives, Jacobian, interchange of the order of differentiation, Derivation of higher order, inverse function theorem, implicit function theorem.

Unit IV **(14 Lecture Hours)**

Riemann Stieltje's Integral: definition and existence of Integral, Properties of integral, integration and differentiation, Riemann sums and Riemann integral, Improper Integrals. Fundamental theorem of Calculus, 1st and 2nd mean value theorems for Riemann Stieltje's integral, Integration of vector valued functions, Rectifiable curves.

Recommended Books:

1. W. Rudin, *Principles of Mathematical Analysis*, 3rd Edition, McGraw Hill, Kogakusha, International Student Edition, 1976.
2. H. L. Royden, *Real Analysis*, 3rd edition, Macmillan, New York & London, 1988.
3. S. C. Malik, *Mathematical Analysis*, Wiley Eastern Ltd, 1992.
4. E. C. Titchmarsh, *The Theory of functions*, 2nd Edition, U.K. Oxford University Press, 1961.
5. T. M. Apostol, *Mathematical Analysis*, 2nd Addition –Wesley, 1974.
6. G. F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill Ltd, 2004.

Course Title: Basic Statistics
Course Code: STA.402
Total Hours: 32

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 **(8 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 **(8 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)**

Correlation and Regression analysis, rank correlation coefficients, curve fitting.

Recommended Books:

1. P. L. Meyer, *Introductory Probability and Statistical Applications*, Oxford & IBH Pub, 1975.
2. R. V. Hogg and A. T. Craig, *Introduction to Mathematical Statistics*, Macmillan Pub. Co. Inc., 1978.
3. F. E. Croxton and D. J. Cowden, *Applied General Statistics*, 1975.
4. P. G. Hoel, *Introduction to Mathematical Statistics*, 1997.

Semester II

Course Title: Computational Methods
Course Code: STA.403
Total Hours: 32

L	T	P	Credits	Marks
2	0	0	2	50

Objectives:
The course on Computational Methods has been framed to equip the students of M.Sc. Statistics with knowledge of programming in C, roots of equation, interpolation, curve fitting, numerical differentiation, numerical integration, solution of ordinary differential equations and probability.

Unit I **(8 Lecture Hours)**

Programming with C: Introduction to the concept of object oriented programming, Advantages of C over conventional programming languages, Introduction to classes, objects, C programming syntax for Input/Output, Operators, Loops, Decisions, Simple and inline functions, Arrays, Strings, Pointers.

Unit II **(8 Lecture Hours)**

Roots of Algebraic and Transcendental Equations: Element of computational techniques: roots of functions, Interpolation, Extrapolation, One point and two-point iterative methods such as bisection method and Newton Raphson methods.

Unit III **(8 Lecture Hours)**

Integration and Differential: Integration by Trapezoidal and Simpson's rule, Solution of first order differential equation using Runge-Kutta methods, Finite difference methods.

Data Interpretation and Error analysis: Dimensional analysis, Precision and accuracy, error analysis, Propagation and errors.

Unit IV **(8 Lecture Hours)**

Least square fitting: Least square fitting, Linear and nonlinear curve fitting, Chi square test.

Random numbers: Introduction to random numbers, Monte Carlo method for random number generation.

Probability Theory: Elementary probability theory, Random variables, Binomial, poisson and normal distributions, Central limit theorem.

Recommended Books:

1. P. R. Bevington and D. K. Robinson, *Data Reduction and Error analysis for Physical Sciences,* McGraw Hill, Noida, India, 2003.
2. Y. Kanetkar, *Let Us C,* BPB Publications, New Delhi, India, 2012.
3. E. Balaguruswamy, *Numerical Methods,* Tata McGraw Hill, Noida, India, 2009.
4 S. S. Sastry, *Introductory Methods of Numerical Analysis,* PHI Learning Pvt. Ltd., New Delhi, India, 2012.

Course Title: Computational Methods (LAB)
Course Code: STA.404
Total Hours: 60

L	T	P	Credits	Marks
0	0	2	2	50

Objectives:
The laboratory exercises have been so designed that the students learn to verify some of the mathematical concepts. They are trained in carrying out numerical problems using C language.

Student has to perform at least eight experiments out of the following list of experiments.

1. Data handling: find standard deviation, mean, variance, moments etc. of at least 25 entries.
2. Choose a set of 10 values and find the least squared fitted curve.
3. To find the roots of quadratic equations.
4. Perform numerical integration on 1-D function using Simpson rules.
5. Perform numerical integration on 1-D function using Trapezoid rule.
6. To generate random numbers between (i) 1 and 0, (ii) 1 and 100.
7. To find the value of π using Monte Carlo simulation.
8. To find the solution of differential equation using Runge-Kutta method.
9. To find the solution of differential equation using Euler's method.
10. To find the value of y for given value of x using Newton's interpolation method.

Recommended Books:

1. P. R. Bevington and D. K. Robinson, *Data Reduction and Error analysis for Physical Sciences*, McGraw Hill, Noida, India. 2003.
2. Y. Kanetkar, *Let Us C*, BPB Publications, New Delhi, India, 2012.
3. E. Balaguruswamy, *Numerical Methods*, Tata McGraw Hill, Noida, India, 2009.
4. S. S. Sastry, *Introductory Methods of Numerical Analysis*, PHI Learning Pvt. Ltd., New Delhi, India, 2012.

Course Title: Linear Models and Regression
Course Code: STA.510
Total Hours: 32

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 **(8 Lecture Hours)**

Linear Estimation: Gauss-Markov linear Models, Estimable functions, Error and Estimation Spaces, Best Linear Unbiased Estimator (BLUE), Least square estimator, Normal equations, Gauss-Markov theorem, generalized inverse of matrix and solution of Normal equations, variance and covariance of Least square estimators.

Unit II **(8 Lecture Hours)**

Test of Linear Hypothesis: One way and two way classifications. Fixed, random and mixed effect models (two way classifications only), variance components.

Unit III **(8 Lecture Hours)**

Linear Regression: 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 variance and detection of outlines. Remedies.

Unit IV **(8 Lecture Hours)**

Non Linear Models: Multi-collinearity, Ridge regression and principal components regression, subset selection of explanatory variables, Mallon's Cp Statistics.

Recommended Books:

1. A. M. Goon, M. K. Gupta and B. Dasgupta, *An Outline of Statistical Theory*, Vol.2, The World Press Pvt. Ltd. Calcutta, 1987.
2. C. R. Rao, *Introduction to Statistical Infererence and its Applications*, Wiley Eastern, 1973.
3. F. A. Graybill, *An Introduction to Linear Statistical Models*, Vol. 1, McGraw Hill Book Co. Inc., 1961.
4. N. R. Draper and H. Smith, *Applied Regression Analysis*, 3rd Ed., Wiley, 1998.
5. S. Weisberg, *Applied Linear Regression*, Wiley, 1985.
6. R. D. Cook and S. Weisberg, *Residual And Inference In Regression*, Chapman & Hall, 1982.

Course Title: Estimation and Testing of Hypothesis
Course Code: STA.511
Total Hours: 45

L	T	P	Credits	Marks
3	0	0	3	75

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 **(12 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 **(12 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. MP and UMP tests in a class of size a tests.

Unit III **(11 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 **(10 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. V. K. Rohatgi, *An Introduction to Probability Theory and Mathematical Statistics*, John Wiley, 1988.
2. C. R. Rao, *Linear Statistical Inference and its Applications*, 2^{nd} Edition, Wiley, 2002.
3. E. L. Lehmann and G. Casella, *Theory of Point, Estimation*, Student Edition, John Wiley & Sons, 1986.
4. A. M. Goon and M. K. Gupta, *An Outline of Statistical Theory,* Vol-II & Dasgupta, B., 2005.
5. B. K. Kale, *A First Course on Parametric Inference*, Narosa Publishing House, 1999.
6. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley, New York , 1998.

Course Title: Estimation and Testing of Hypothesis (LAB)
Course Code: STA.512
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: Mathematical Programming
Course Code: STA.513
Total Hours: 56

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 programming as well transportation problem.

Unit I **(14 Lecture Hours)**

Formulation of linear programming problem (LPP), graphical solution to LPP, properties of a solution to the (LPP) generating extreme point solutions. The simplex computational procedure, development of minimum feasible solution, a first feasible solution using slack variables, the artificial basis technique. Two phase method and Charnes M-method with artificial variables. Duality in Linear Programming: Symmetric and Un-Symmetric dual Problems. Fundamental Duality Theorem. Dual simplex method. Complementary Slackness Theorem. Sensitivity Analysis.

Unit II **(14 Lecture Hours)**

Transportation Problems: balanced and unbalanced. Initial basic feasible solution of transportation problems by North West Corner Rule, Lowest Cost Entry Method and Vogel's Approximation Method. Optimal Solution of Transportation Problems. Assignment problems and their solution by Hungarian assignment method. Reduction Theorem. Unbalanced assignment problem. Sensitivity in assignment problems.

Unit III **(14 Lecture Hours)**

Replacement problem, replacement of items that Deteriorate, replacement of items that fails completely Individual Replacement policy : Mortality theorems, Group replacement policy, Recruitment and promotion problems.

Unit IV **(14 Lecture Hours)**

Inventory Management**:** Characteristics of inventory systems. Classification of items. Deterministic inventory systems with and without lead-time. All units and incremental discounts. Single period stochastic models. Job Sequencing Problems; Introduction and assumption, Processing of n jobs through two machines(Johnson's Algorithm) Processing of n jobs through three machines and m machines, Processing two jobs through n machines(Graphical Method)

Recommended Books:

1. S. I. Gass, *Linear Programming*, Dovers, 2003.
2. N. S. Kambo, *Mathematical Programming*, East West Press, 2008.
3. S. D. Sharma, *Operations Research,* Kedarnath Amarnath, Meerut, 2009.
4. G. Hadley, *Linear Programming*, Addison Wesley, 1977.
5. S. M. Ross, *Simulation*, 4th Edition, Academic Press, 2006.
6. G. Hadley and T. M. Whitin, *Analysis of Inventory Systems*, Prentice Hall, 1963.
7. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, 7th Edition, Irwin, 2001.
8. H. A. Taha, *Operations Research: An Introduction*, 8th Edition, Prentice Hall, 2006.
9. B. M. Wagner, *Principles of OR,* Englewood Cliffs, N. J., Prentice-Hall, 1975.

Course Title: Actuarial Statistics
Course Code: STA.514
Total Hours: 56

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 **(12 Lecture Hours)**

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

Unit III **(12 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. A. Klugman, H. H. Panjer, G. E. Willmot and G. G. Venter, *Loss Models: From Data to Decisions*. 3rd Edition, Wiley-Interscience, 2008.
3. P. J. Boland, *Statistical and Probabilistic Methods in Actuarial Science*, Chapman and Hall/CRC, 2007.
4. D. S. Borowaik and A. F. Shapiro, *Financial and Actuarial Statistics: An Introduction*, Marcel Dekker Inc., New York-Basel, 2005.
5. S. D. Promislow, Fundamentals of Actuarial Mathematics, 2nd Edition, Wiley, 2011

Course Title: Fundamentals of Computer Science and Programming in C, C++
Course Code: STA.515
Total Hours: 45

L	T	P	Credits	Marks
3	0	0	3	75

Objectives:
The course on Fundamentals of Computer Science and Programming in C, C++ has been framed to equip the students of M.Sc. Statistics with knowledge of programming in computer languages.

Unit I **(11 Lecture Hours)**

Basic Concepts: Historical development of C, Primary memory, Secondary storage devices, Input and Output devices, 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.

Unit II **(12 Lecture Hours)**

C Programming: Introduction to algorithm, Flow charts, Problem solving methods, Need of programming languages. C character set, Identifiers and keywords, Data types, Declarations, Statement and symbolic constants, Input-output statements, Preprocessor commands, Operators, expressions and library functions, decision making and loop control statements, Functions, Storage Classes, Arrays, Strings, Pointers, Structure and union, File handling.

Unit III **(11 Lecture Hours)**

Basic concepts of Object-Oriented Programming (OOP). Advantages and applications of OOP. Object-oriented languages. Introduction to C++. Structure of a C++ program. Creating the source files. Compiling and linking, **C++ programming basics**: Input/Output, Data types, Operators, Expressions, Control structures, Library functions.

Unit IV **(11 Lecture Hours)**

Functions in C++ : Passing arguments to and returning values from functions. **Classes and objects** : Specifying and using class and object, Arrays within a class, Arrays of objects, Object as a function arguments. **Operator Overloading and Type Conversions**: Overloading unary, binary operators. **Inheritance**: General concepts of Inheritance, Types of derivation-public, private, protected.

Recommended Books:

1. P. Norton, *Introduction to Computers*, Tata McGraw Hill, 2008.
2. B. W. Kerninghan and D. M. Ritchie, *The C Programming Language*, PHI, 1989.
3. Y. Kanetkar, *Let Us C*, BPB, 2007.
4. Deitel and Deitel, *C++ How to Program*, Pearson Education, 2004.
5. E. Balaguruswamy, *Objected Oriented Programming with C++*, Tata McGraw Hill, 2008.
6. Y. Kanetkar, *Let Uc C++*, BPB, 1999.

Course Title: Fundamental of Computer science and programming in C and C++ (LAB)
Course Code: STA.516

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: Demography and Vital Statistics
Course Code: STA.517
Total Lectures: 56

L	T	P	Credits	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 **(14 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 **(14 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 **(14 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 **(14 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, J. A. Beckman, *Demography through Problems*, S-Verlag New York, 1984.
2. D. I. Bartholomew, *Stochastic Models for Social Process*, John Wiley, 1982.
3. C. L. Chiang, *Introduction to Stochastic Process in Biostatistics*, John Wiley, 1968.
4. P. R. Cox, *Demography*, Cambridge University press, 1970.
5. N. Keyfitz, *Applied Mathematical Demography*, Springer Verlag, 1977.
6. M. Spiegelman, *Introduction to Demography Analysis*, Harvard University press, 1969.
7. R. Ramkumar, *Technical Demography*, New Age International, 1986.
8. A. J. Coale, *The Growth And Structure of Human Population*, Princeton, 1972.
9. N. Keyfitz, *An Introduction to Mathematics of Population*, Springer, 1971.
10. D. J. Bogue, *Principles of Demography*, Wiley, 1969.

Course Title: Reliability Theory
Course Code: STA.518
Total Hours: 56

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 **(14 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 **(14 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 **(14 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 **(14 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*, Holt, Rinehart and Winston, 1985.
2. J. F.Lawless, *Statistical Models and Methods of Life Time Data*, John Wiley Models, Marcel Dekker, 1982.
3. M. Shaked and J. G. Shanthikumar, *Stochastic Orders & Their Applications*, Academic Press, 1994.

Course Title: Statistical Simulation
Course Code: STA.519
Total Hours: 56

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 **(14 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 **(14 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.
3. T. T. Julius and R. C. Gonzalesz, *Pattern Recognition Principles*, Addison – Wesley Publishing Company, 1997.

Course Title: Basics of Inferential Statistics
Course Code: STA.405

L	T	P	Credits	Marks
2	0	0	2	50

Total Hours: 32

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 **(8 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 distribution 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. **Types of Inferential Statistics: Estimation and Testing of Hypothesis**. **Estimation**: Point Estimation and Confidence Interval. **Testing of Hypothesis**: Simple and Composite Hypothesis. Difference between parametric tests and non-parametric tests. Level of significance, acceptance region, rejection region, Type I error (α), Type II error (β), confidence interval.

Unit III **(8 Lecture Hours)**

Parametric tests:-

One sample: z-test, student's t-test, F and chi-square test. **Two sample:** z-test, student's t-test, F, chi-square. Paired t-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. F. D. Gibbons, *Non-parametric Statistical Inference*, Mc Graw Hill Inc, 1971.
3. E. L. Lehmann and G. Casella, *Theory of Point, Estimation*, Student Edition, John Wiley & Sons, 1986.
4. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences*, 10^{th} Edition, John Wiley & Sons, 2013.

Semester III

Course Title: Research Methodology-II
Course Code: STA.406
Total Hours: 32

L	T	P	Credits	Marks
2	0	0	2	50

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 **(8 Lecture Hours)**

Formulation of Research Problem and Hypothesis:
Research problem: How to proceed? Necessary Conditions for formulation of research problem, Sources of research problem, Criteria of a Good Research Problem, formulation and stating the problem, Common errors.
Hypothesis: The meaning, Importance, Type of sources, Characteristics of a usable hypothesis, The use of hypothesis in different types of research, Different forms of hypothesis in different types of research, Different forms of hypothesis, Difficulties in formulation of hypothesis, Testing the hypothesis.

Unit II **(8 Lecture Hours)**

Literature Survey: References, Abstraction of a research paper, Possible ways of getting oneself abreast of current literature.

Unit III **(8 Lecture Hours)**

Documentation and Scientific Writing: Result and conclusions; Preparation of manuscript for publication of research paper, Presenting a paper in scientific seminar, thesis writing.
Structure and components of research report, Types of reports, Thesis, Research project reports, Pictures and graphs, Citation styles, Writing a review of paper, Bibliography.

Unit IV **(8 Lecture Hours)**

Computer Applications: Use of word processing, Spreadsheet and database software. Plotting of graphs. Internet and its applications: Email, WWW., Web browsing, acquiring technical skills, drawing inferences from data.

Recommended Books:

1. S. Gupta, *Research Methodology and Statistical Techniques*, Deep and Deep Publications, 1999.
2. J. Anderson, B. H. Dursten and M. Poole, *Thesis & Assignment Writing*, Wiley Eastern, 1977.
3. M. Alley, *The Craft of Scientific Writing*, 3rd Corrected Edition, Springer, 1998.
4. R. A. Day and B. Gastel, *How to Write and Publish*, 7th Revised Edition, Cambridge University Press, 2011.
5. R. Kumar, *Research Methodology-A Step by Step Guide for Beginners*, Pearson Education, 2005.

Course Title: Numerical Analysis
Course Code: STA.601

L	T	P	Credits	Marks
3	0	0	3	75

Total Hours: 45

Objectives:

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, Order of convergence, Newton's method for two non linear equations.

Unit II **(11 Lecture Hours)**

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

Eigen Value Problems: Power method and Jacobi method.

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

Unit III **(12 Lecture Hours)**

Spline and Approximation: Cubic Spline, B-Spline, Least square method, Påde approximation, Chebyshev Approximation.

Numerical Differentiation: Numerical differentiation with finite differences, Errors in numerical differentiation.

Numerical Integration: 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, Predicator-Corrector Methods. Finite difference method for boundary value problems.

Recommended Books:

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

Course Title: Numerical Analysis (LAB)
Course Code: STA.602
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.

Course Title: Measure Theory
Course Code: STA.603
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

Objectives:
The objective of this course is to introduce student's measure theory in an abstract setting after having studied Lebesgue measure on real line. The general L^p spaces are also studied.

Unit I **(13 Lecture Hours)**

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

Unit II **(14 Lecture Hours)**

Borel sets, Lebesgue outer measure and Lebesgue measure on R, Translation invariance of Lebesgue measure, Existence of a non-measurable set, Characterizations of Lebesgue measurable sets, The Cantor-Lebesgue function.

Unit III **(14 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 (statement only), Lebesgue integral on R and its properties.

Unit IV **(15 Lecture Hours)**

Bounded convergence theorem, Fatou's lemma, Lebesgue monotone convergence theorem, Lebesgue dominated convergence theorem, 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. G.B. Folland, *Real Analysis,* 2nd Edition, John Wiley, New York, 1999.
4. E. Kreyszig, *Introductory Functional Analysis with Applications*, John Wiley, 1989.
5. I. K. Rana, *An Introduction to Measure and Integration,* 2nd Edition, Narosa Publishing House, New Delhi, 2005.
6. P. R. Halmos, *Measure Theory, Grand Text Mathematics*, 14th Edition, Springer, 1994.
7. B. Krishna and A. Lahiri, *Measure Theory*, Hindustan Book Agency, 2006.
8. T. Tao, *An Introduction To Measure Theory*, American Mathematical Society, 2012.

Course Title: Quality Control and Time series
Course Code: STA.604
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*, Mc Graw Hill, New York, 1976.
3. D. C. Montgomery, *Introduction to Statistical Quality Control*, 5th Edition., John Wiley & Sons, 2005.
4. P. J. Brockwell and A. Daris Richard, *Introduction to Time Series And Forecasting*, 2nd Edition. Springer-Verlag, New York, Inc. (Springer Texts in Statistics), 2002.
5. G. B. Wetherill, *Sampling Inspection and Quality Control*, Halsted Press, 1977.

Course Title: Quality Control and Time Series (LAB)
Course Code: STA.605
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: Econometrics
Course Code: STA.606
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. J. Johnston, *Econometric Methods*, Mc Graw Hill, 1991.
2. J. Kmenta, *Elements of Econometrics*, 2nd Edition, Mac Millan, 1986.
3. W. H. Greene, *Econometric Analysis*, Prentice Hall, 2003.
4. D. N. Gujarati, *Basic Econometrics*, 4th Edition, McGraw−Hill, 2004.
5. A. Koutsyannis, *Theory of Econometrics, Mc Millian, 2004.*
6. 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.607
Total Hours: 30

L	T	P	Credits	Marks
0	0	2	1	25

Laboratory work should be related with the theory.

Course Title: Stochastic Processes
Course Code: STA.608
Total Hours: 56

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 **(14 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 **(16 Lecture Hours)**

Random walk and gambler's ruin problem. Applications of stochastic processes. Stationarity of stochastic processes, Weakly stationary and strongly stationary processes.
autocorrelation, power spectral density function.
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 **(13 Lecture 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 **(13 Lecture 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*, 2nd Edition ,Wiley Eastern Ltd., 1994.
2. N. T. Bailey, *The Elements of Stochastic Processes*, John Wiley & Sons, Inc., New York, 1965.
3. S. M. Ross, *Stochastic Processes,* Wiley Publications, 1996.

Course Title: Seminar
Course Code: STA.599
Total Hours: 32

L	T	P	Credits	Marks
-	-	4	2	50

Semester IV

Course Title: Multivariate Analysis
Course Code: STA.609
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, 1983.
2. N. C. Giri, *Multivariate Statistical Inference*. Academic Press, 1977.
3. A. M. Kshirsagar, *Multivariate Analysis*, Marcel Dekker, 1972.
4. C. R. Rao, *Linear Statistical Inference and its Application*, 2nd Edition, Wiley, 2002.

Course Title: Multivariate Analysis (LAB)
Course Code: STA.610

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 theory.

Course Title: Design and Analysis of Experiment
Course Code: STA.611
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.

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Recommended Books:

1. O. Kempthorne, *Design and Analysis of Experiments Vol I-II*, Wiley, 2007.
2. D. Raghavarao, *Construction and Combinatorial Problems in Design of Experiments*, Wiley, 1971.
3. M. C. Chakarbarti, *Mathematics of Design and Analysis of Experiments*, Asia Publishing House, 1970.
4. M. N. Dass and N. C. Giri, *Design and Analysis of Experiments*, New Age International Publishers, 1986.
5. W. G. Cochran and G. M. Cox, Design of Experiments, Wiley, 1992.
6. D. C. Montgomery, *Design and Analysis of Experiment*, Wiley, 2004.

Course Title: Design and Analysis of Experiment (LAB)
Course Code: STA.612
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: Dissertation Research
Course Code: STA.600
Total Hours: 180

L	T	P	Credits	Marks
0	0	16	8	200

Course Title: Advanced Numerical Methods
Course Code: STA.613

L	T	P	Credits	Marks
4	0	0	4	100

Total Hours: 56

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 **(15 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 **(13 Lecture Hours)**

Eigen-Values of Real Symmetric Matrix: Similarity transformations, Gerschgorin's bound(s) on eigenvalues, 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 **(13 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 **(15 Lecture Hours)**

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

Recommended Books:

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

Course Title: Game Theory and Non-Linear Programming
Course Code: STA.614
Total Hours: 56

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 **(14 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 **(14 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 **(14 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 **(14 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, East West Publisher, 2008*.
2. R. Bellman, *Dynamic Programming,* Princeton University Press, Princeton, New Jersey,1957
3. R. Bellman, and S. Dreyfus, *Applied Dynamic Programming*, Princeton University Press, Princeton, New Jersey, 1963.
4. S. D. Sharma, *Operations Research*, Kedarnath Amarnath, Meerut, 2009.

Course Title: Non-Parametric Inference
Course Code: STA.608
Total Hours: 56

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 **(14 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 **(14 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 II I **(14 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 **(14 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, *Nonparametrics Statistical Inference*, 2nd Edition, Marcel Dekker, Inc, 1985.
2. R. H. Randles and D. A. Wolfe, *Introduction to the Theory of Nonparametric Statistics*, John Wiley and Sons, 1979.
3. A. C. Davison and D. V. Hinkley, *Bootstrap Methods and their Application*, Cambridge University Press, 1997.
4. W. W. Daniel, *Applied Nonparametric Statistics*, 2nd Edition, 2000.

Course Title: Investment Risk Analysis
Course Code: STA.616
Total Hours: 56

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 **(14 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 **(14 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 **(13 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*, 8th Edition, Tata McGraw Hill, 2009.
2. D. Ruppert, *Statistics and Finance*, Springer, 2004.

Course Title: Economic Statistics
Course Code: STA.617
Total Hours: 56

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 measures to measure risk will be studied in this course.

Unit I **(14 Lecture Hours)**

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

Unit II **(14 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 **(14 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 **(14 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*, 1980.
2. P. Lambert, *The Distribution and Redistribution of Income*, 2001.
3. N. C. Kakwani, *Income Inequality and Poverty: Method of Estimation and Policy Applications*, Oxford University Press, 1980.
4. P. A. Samuelson and W. D. Nordheus, *Economics*, 1998.

Course Title: Queuing theory and Advanced Stochastic Processes
Course Code: STA.618
Total Hours: 56

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 Queuing theory and Advanced Stochastic Process.

Unit I **(14 Lecture Hours)**

Queuing Theory**:** Steady state analysis of M/M/1, M/M/C queues. Method of stages for steady state solution of $M/E_r/1$ and $E_r/M/1$ queues. Simple design and control problems in queuing theory.

Unit II **(14 Lecture Hours)**

Non-Markovian Queuing Systems: Concept of imbedded Markov chain, Steady state solution, Mean number of arrivals, expected queue length and expected waiting time in equilibrium.

Unit III **(14 Lecture Hours)**

Inventory Models: Classification of inventory models, Deterministic inventory model (DIM), Basic Economic order Quantity (EOQ)models with no shortages, DIM with Shortages, EOQ with finite replenishment, EOQ with price break, single multi- item deterministic inventory models. Inventory problems with uncertain demand, Probabilistic (Stochastic) inventory models, Determination of Reserve Stock, Q-System/ P System, Uniform Demand & discrete units, instant demand & discrete units.

Unit IV **(14 Lecture Hours)**

Stochastic processes on survival and competing risk theory: Measurement of competing risks, inter-relations of probabilities, estimation of crude, net & partially crude probabilities, Neyman's modified X^2 method, Independent & dependent risks.

Recommended Books:

1. J. Medhi, *Stochastic Processes*, Wiley Eastern, 2nd Ed, 1994.
2. D. Gross and C. M. Harris, *Fundamental of Queuing Theory*, Wiley, 1985.
3. S. Biswas, *Applied Stochastic Processes*, Wiley, 1995.