**M.Sc. Statistics Program**
**Under Credit and Semester System (CSS) 2012 onwards**

| Course Code | Course Title | Credits | Teaching Hours/Week |
|---|---|---|---|
| | **Semester-I (Total credits-20)** | | |
| ST1C01 | Distribution Theory | 4 | 5 |
| ST1C02 | Analytical Tools for Statistics | 4 | 5 |
| ST1C03 | Probability Theory | 4 | 5 |
| ST1C04 | Mathematical Methods for Statistics | 4 | 5 |
| ST1C05 | Statistical Computational Techniques | 4 | 5 |
| | **Semester-II (Total credits-20)** | | |
| ST2C06 | Multivariate Distributions | 4 | 5 |
| ST2C07 | Advanced Probability Theory | 4 | 5 |
| ST2C08 | Statistical Estimation Theory | 4 | 5 |
| ST2C09 | Stochastic Processes | 4 | 5 |
| ST2C10 | Statistical Computing-1 | 4 | 5 |
| | **Semester-III (Total credits-20)** | | |
| ST3C11 | Sampling Theory | 4 | 5 |
| ST3C12 | Statistical Testing of Hypotheses | 4 | 5 |
| ST3C13 | Design and Analysis of Experiments | 4 | 5 |
| ST3C14 | Multivariate Analysis | 4 | 5 |
| ST3C15 | Statistical Computing-2 | 4 | 5 |
| | **Semester-IV (Total credits-20)** | | |
| ST4C16 | Statistical Quality Control | 3 | 5 |
| ST4 E01: | Econometric Methods | 3 | 5 |
| ST4 E02: | Operations Research | 3 | 5 |
| ST4 E05: | Statistical Decision Theory | 3 | 5 |
| ST4 E08: | Statistical Computing-3 | 3 | 5 |
| ST4 CD | Dissertation/Project | | 3 |
| ST4 CV | Viva-Voce | | 2 |

## ST1C01 Distribution Theory

Our everyday lives, as well as economic and business activities, are full of uncertainties and probability and distribution theory offer useful techniques for quantifying these uncertainties. The course is heavily oriented towards the formulation of mathematical concepts on probability distributions and densities with practical applications.

Topics covered are: discrete random variables, moments, probability generating functions, standard discrete distributions; continuous random variables, uniform and chi-square distributions, transformations, marginal and conditional distributions, bivariate normal distribution. Power series, Binomial, Geometric, Poisson, Negative binomial and Hyper geometric and Continuous Distributions:- Rectangular, Exponential, Weibull, Beta, Gamma, Pareto, Normal, Lognormal, Cauchy, Laplace, Logistic.

At the end of the course students should be able to:

- How to derive the probability density function of transformations of random variables and use these techniques to generate data from various distributions.
- Apply selected probability distributions to solve problems.
- Present the analysis of derived statistics to all audiences.
- To apply all the discrete distributions for analysing the data.
- To use various continuous distributions whenever necessary.
- To describe the practical applications of truncated distribution.
- To apply order statistics for distribution theory.

## ST1C02 Analytical Tools for Statistics

The course present

- Basic concepts of matrices and matrix algebra.
- Methods of solving systems of linear equations.
- Basic concepts of vector spaces.
- Concepts of linear transformations.
- The concept of and methods of computing determinants.
- Methods of computing and using eigenvalues and eigenvectors.

Students in this course will:

- Demonstrate ability to manipulate matrices and to do matrix algebra.
- Demonstrate ability to solve systems of linear equations.
- Demonstrate ability to work within vector spaces and to distil vector space properties.
- Demonstrate ability to manipulate linear transformations and to distil mapping properties.
- Demonstrate ability to manipulate and compute determinants.
- Demonstrate ability to compute eigenvalues and eigenvectors.

## ST1C03 Probability Theory

Probability theory is the branch of mathematics that deals with modelling uncertainty. It is important because of its direct application in areas such as genetics, finance and telecommunications. It also forms the fundamental basis for many other areas in the mathematical sciences including statistics, modern optimisation methods and risk modelling.

This course provides an introduction to probability theory, random variables and Markov processes. Topics covered are: probability axioms, conditional probability; Bayes' theorem; discrete random variables, moments, bounding probabilities.

## ST1C04 Mathematical Methods for Statistics

This course will give the students an idea regarding

- Sequences and series of functions convergence, continuity, uniform continuity, differentiability. Functions of several variables: maxima and minima, Method of Lagrangian multipliers, Riemann integration theory Laplace transform and its applications to differential equations.
- Different measures, measurable and measure space measurable set and its properties are discussed
- Lebesgue integration theory and general definition of integral and very important three theorem such as Fatou's lemma. monotone convergence theorem, Lebesgue dominated convergence theorem are covered in this course
- Basic ideas of complex numbers and complex functions are covered in this paper. Analytic functions, Cauchy-Riemann equations, contour integral, Cauchy's theorem Cauchy's integral formula, Liouville's theorem, Maximum modulus principle, Zeroes of a function, singular point, different types of singularities, residues at a pole.

This course helps the students to ensure a strong base to tackle the problems in probability theory.

## ST1C05 Statistical Computational Techniques

The course in Statistical Computational Techniques consists of two major parts - topics on numerical analysis and basic concepts of the open source software R. It will develop numerical methods aided by technology to solve algebraic, transcendental, and differential equations, and to calculate derivatives and integrals. The course will also develop an understanding of the elements of error analysis for numerical methods and certain proofs. The course will further develop problem solving skills.

Course Objectives includes

- Derive appropriate numerical methods to solve algebraic and transcendental equations.
- Develop appropriate numerical methods to approximate a function.
- Develop appropriate numerical methods to solve a differential equation.
- Derive appropriate numerical methods to evaluate a derivative at a value.
- Derive appropriate numerical methods to solve a linear system of equations.
- Perform an error analysis for various numerical methods.
- Prove results for various numerical root finding methods.
- Derive appropriate numerical methods to calculate a definite integral.
- Code various numerical methods in a modern computer language.

After completion of the course students will be able to

- Solve an algebraic or transcendental equation using an appropriate numerical method.

- Approximate a function using an appropriate numerical method.
- Solve a differential equation using an appropriate numerical method.
- Evaluate a derivative at a value using an appropriate numerical method.
- Solve a linear system of equations using an appropriate numerical method.
- Perform an error analysis for a given numerical method.
- Prove results for numerical root finding methods.
- Calculate a definite integral using an appropriate numerical method.
- Code a numerical method in a modern computer language.

The course outcome will be a foundation for fluency in R programming, and an insight into the capabilities of the language as a productivity tool for data manipulation and statistical analyses.

**ST2C06 Multivariate Distributions**

The objective of the course is to introduce several useful multivariate techniques, making strong use of illustrative examples and a minimum of mathematics. The course will start with the extensions of univariate techniques to multivariate framework, such as multivariate normal distribution, hypothesis testing.

Multivariate analysis skills have been commonly recognized as part of the key requisites for analytics analysts. The complexity of most phenomena in the real world requires an investigator to collect and analyze observations on many different variables instead of a single variable. The desire for statistical techniques to elicit information from multivariate dimensional data thus becomes essential and crucial for data analysts. The course provides an insight of the notions of bivariate distributions such as Gumbel's bivariate exponential and bivariate normal distribution, multinomial distribution, multivariate normal and Wishart distribution and their properties.

**ST2C07 Advanced Probability Theory**

The course will give the student a deeper understanding of the foundations of probability theory, such as probability theory from a measure-theoretic perspective, convergences of distributions and probability measures, and conditional expectations. During the course, important theorems, such as Borell-Cantelli lemma, Radon-Nikodym theorem, Fubini theorem, and general central limit theorems, will be investigated. The syllabus also covers advanced topics in characteristic functions and its convergence properties.

Completing this course, the student must be able to know and understand

- A count of the foundations of probability theory from a measure-theoretic perspective.
- Define and relate different types of convergences of distributions, probability measures and characteristic functions.
- Describe theory for conditional distributions and expectation from a measure-theoretic perspective.
- Define and relate different types of martingales and its use in practical situations.

## ST2C08 Statistical Estimation Theory

After completing this course, the students will be able to:

- Understand problem of statistical inference, problem of point estimation.
- Properties of point estimator such as Consistency, Unbiasedness, Sufficiency and Efficiency.
- Obtain minimum variance unbiased estimator.
- Obtain estimators using estimation methods such as Maximum likelihood, Minimum chi square, method of moments. Method of scoring, Properties of maximum likelihood estimator.
- Quantify information in statistic using Fisher Information.
- Construct minimal sufficient statistic and minimal sufficient statistic for exponential family.
- Understand concept of Rao-Blackwell theorem and complete family.
- Understand problem of statistical inference, problem of Interval estimation.
- Construction of Confidence Interval (one and two parameter case).

## ST2C09 Stochastic Processes

Stochastic models are among the most widely used tools in operations research and management science. Stochastic processes and its applications can be used to analyse and solve a diverse range of problems arising in production and inventory control, resource planning, service systems, computer networks and many others. This course, with an emphasis on model building, covers inventory models, Markov chains, Poisson processes, queuing theory, branching process and renewal process. At the end of this Course Students will be able:

- To apply various inequalities in Mathematical as well as Statistical Analysis.
- To use birth and death Poisson processes whenever necessary.
- To study the applications of Gambler's Ruin problems.
- Elucidate the power of stochastic processes and their range of applications.
- Demonstrate essential stochastic modelling tools including Markov chains and queuing theory.
- Formulate and solve problems which involve setting up stochastic models.
- To apply stochastic models for different distributions.

## ST2C10 Statistical Computing-1

This course covers the practical problems of Distribution theory, Estimation theory, Multivariate distributions and stochastic process. This course develops the computational skill and familiarity in data analysis techniques in real life situations using MS excel or R packages.

## ST3C11 Sampling Theory

By the end of this course students are expected to be able to apply and use the basic concepts related to sampling techniques, to determine sample size so as the estimator will have a desired precision and to use appropriate sampling method and determine optimum sample

sizes. This course is concerned with the design of sample surveys and the statistical analysis of data collected from such surveys. Topics covered are: Simple random sampling with associated estimation and confidence interval methods, Selecting sample sizes, Estimating proportions, Unequal probability sampling, Ratio and regression estimation, Stratified sampling, Cluster and systematic sampling, Multistage designs and Double or Two-stage sampling. At the End of this Course Students will be able to:

- Various sampling inspection techniques.
- To apply various sampling methods for agricultural data.
- To explain and to compare various allocations using stratified random sampling.
- To draw a conclusion about the best sampling procedure.
- To use practical applications of ratio and regression method of estimation.

The aim of this course is to cover sampling design and analysis methods that would be useful for research and management in many fields. A well designed sampling procedure ensures that we can summarize and analyse data with a minimum of assumptions and complications.

## ST3C12 Statistical Testing of Hypotheses

By the end of this course, the students will be able to:

- Understand problem of statistical inference, problem of testing of hypothesis.
- Explain critical regions, test functions, two kinds of errors, size function and power function.
- Construct Most Powerful test using NP Lemma.
- Understand situation when UMP test exists.
- Construct Uniformly Most Powerful testing one parameter exponential family and Pitman family.
- Understand the concept of Non-existence of UMP test.
- Explain Likelihood ratio test.
- Understand Sequential probability ratio test.
- Advantages and disadvantages of Non parametric tests (NPT).
- Various one sample and two sample NPT such as test of randomness, Sign test, Kolmogorov Smirnov (KS) test, Mann - Whitney U test, etc.

This course will help to solve the testing problems in real life situations.

## ST3C13 Design and Analysis of Experiments

At the End of this Course Students will be able:

- Use statistics in experimentation.
- Understand the important role of experimentation in new product design, manufacturing process development, and process improvement.
- To apply various designs for agricultural data/agricultural field.
- To explain which design will give the maximum yield of a crop.
- To use factorial experiment for agriculture data.

- Become familiar methodologies that can be used in conjunction with experimental designs for robustness and optimization.
- To describe the concept of confounding for different experiment.

**ST3C14 Multivariate Analysis**

The central theme of the course is the multivariate general linear model, and statistical methods include multivariate hypothesis testing, principal component analysis, factor analysis, discriminant analysis, canonical correlation analysis, and multivariate analysis of variance and covariance and cluster analysis. The course covers theoretical, computational, and interpretative issues of multivariate techniques using computer solution.

Learning outcomes includes

- On a general level the students should be able to understand the concept of analyzing multivariate data.
- They should be familiar with a basic minimum level of matrix competency and with general aspects of handling multivariate data. On successful completion of the course the student.
- Will appreciate the range of multivariate techniques available.
- Will be able to summarize and interpret multivariate data.
- Will have an understanding of the link between multivariate techniques and corresponding univariate techniques.

At the end of this course, student will be able to use multivariate techniques appropriately, undertake multivariate hypothesis tests, and draw appropriate conclusions.

**ST3C15 Statistical Computing-2**

This course covers the practical problems of Sampling theory, Testing of Hypothesis, Multivariate distributions and Design of experiments. This course develops the computational skill and familiarity in data analysis techniques in real life situations. This practical awareness help the students to get familiarity with data sets and different techniques using MS excel or R packages.

**ST4C16 Statistical Quality Control**

The goal of the course is to introduce students to statistical quality control (SQC) emphasizing those aspects which are relevant for SQC's practical implementation. This course will present the theory and methods of quality monitoring including process capability, control charts, acceptance sampling, quality engineering, and quality design. The objectives include

- To understand the basic concepts of quality monitoring.
- To understand the statistical underpinnings of quality monitoring.
- To learn various available statistical tools of quality monitoring.
- To learn the statistical and economical design issues associated with the monitoring tools.
- To demonstrate the ability to design and implement these tools.

After completing the course on Statistical Quality Control, the student will understand the concepts of Quality Control and Statistical Process Control (SPC), Control Charts for Variables, Natural and assignable causes of variation, Setting Mean Chart Limits, Setting Range Chart Limits, Using Mean and Range Charts, Control Charts for Attributes, Managerial Issues and Control Charts, Process Capability, Producer's and consumer's risk, Acceptance Sampling, Operating Characteristic (OC) Curves and Average Outgoing Quality.

## ST4 E01 Econometric Methods

Regression analysis is the most common statistical modelling approach used in data analysis and it is the basis for advanced statistical modelling. In this course, students will learn the use of different useful tools used in regression analysis. They will learn about simple and multiple linear regression, non-linear regression and Generalise linear models (GLM) including logistic regression

After learning this course, students will be able to

- Understand the concept of linear and multiple regressions.
- Check for the violations of model assumptions using residual analysis and other statistical tests.
- Understand the problems of multicollinearity, variable selection and how to deal with them.
- Interpretation and critical evaluation of the outcomes of empirical analysis.
- Elementary procedures for model validation in the single equation context.
- Theoretical background for the standard methods used in empirical analyses, like properties of least squares estimators and the statistical testing of hypothesis.

## ST4 E02 Operations Research

Operations research (OR) have many applications in science, engineering, economics, and industry and thus the ability to solve OR problems are crucial for both researchers and practitioners. Being able to solve the real life problems and obtaining the right solution requires understanding and modelling the problem correctly and applying appropriate optimization tools and skills to solve the mathematical model.

In particular, we will cover linear programming, network flow problems, nonlinear programs, dynamic programming, solve specialized linear programming problems like the transportation and assignment problems, solve network models like the shortest path, minimum spanning tree, and maximum flow problems, understand how to model and solve problems using dynamic programming, learn optimality conditions for single- and multiple-variable unconstrained and constrained non-linear optimization problems and corresponding solution methodologies.

By the end of this course, the students will be able to:

- Understand basic concepts of inventory problems and solve various types of EOQ models.
- Gain knowledge about sequencing problems, travelling salesman problem and various methods to solve sequencing problems.

- Understand basic concepts of queuing models and will be able to write and solve the steady state equations for various queuing models.
- Understand different concepts of Network Analysis, Construct Network Diagrams, draw conclusion from Network using PERT analysis and CPM analysis.

The goal of this course is to teach the students to formulate, analyse, and solve mathematical models that represent real-world problems.

**ST4 E05 Statistical Decision Theory**

Learning Objectives/Outcomes: The students will familiarize with fundamental concepts of the statistical decision theory and Bayesian inference. At the end of the course, they are expected to be able to formulate a decision theoretic approach to the problem, evaluate a utility function, propose a conjugate family of prior distributions, evaluate Bayes and posterior risks and find the optimal solution. The students will be able to apply empirical and hierarchical Bayes approaches, will solve statistical games and find maximin and minimax strategies when playing against an intelligent opponent.

At the end of this course, the students will have knowledge of

- Decision Problem, Bayes Rules and minimax rules.
- Bayes' theorem for inference, prior and posterior densities.
- Conjugate priors, non-informative prior, discrete prior, single parameter models.
- Normal distribution with known variance and unknown mean, normal with known mean and unknown variance.
- Basic elements of game theory and the general techniques of solving games.

**ST4 E08 Statistical Computing-3**

This course covers the practical problems of Statistical Quality Control, Econometric Methods and Operations Research. This course develops the computational skill and familiarity in data analysis techniques using MS excel or R packages.