Maa Shakumbhari University, Saharanpur

Syllabus of M.Sc. Statistics (CBCS)
(B.Sc. in Research- Statistics)

(As per the Guidelines of U.P. Government according to National Education Policy (NEP) - 2020 w.e.f. Session 2023-2024)

Members from the Board of Studies (BOS):

S.No.	Name	Signature
1.	**Prof. Ram Kishan**, Department of Statistics, D.A.V. (P.G.) College, Muzaffarnagar **(Convener)**	
2.	**Prof. Hare Krishna**, Department of Statistics, C.C.S. University, Meerut **(External Expert)**	
3.	**Prof. V.K. Tyagi**, Department of Statistics, M.M. (P.G.) College, Modinagar **(External Expert)**	
4.	**Dr. Saurabh Kumar Pandey**, Department of Statistics, R.K.College, Shamli **(Member)**	

Program prerequisites

To study this course, a student must have had the subject Statistics at UG Level.

Program Structure

The program (course) will be based on Choice Based Credit System (CBCS) developed by the University. There will be four compulsory or elective (Optional) core courses of Statistics in each semester. In addition, one minor elective course of other faculty is to be selected by a student in the first year of M.Sc. (Statistics). There will be one 4-credit research project in each semester.

Programme Outcomes (POs)

PO1: Gain sound knowledge in theoretical and practical aspects of Statistics.
PO2: Apply various statistical tools in real life problems.
PO3: Describe complex statistical ideas to non-statisticians.
PO4: Handle and analyse large databases with computer skills and use their results and interpretations to make practical suggestions for improvement.
PO5: Get a wide range of job opportunities in industry as well as in the government sector.

Programme Specific Objectives (PSOs)

After completion of this course, the student would be able

PSO1: To apply the knowledge of Statistics in all fields of learning, including higher research and its extensions.
PSO2: To inculcate and develop the aptitude to apply statistical tools in a number of data-generating fields in real-life problems.
PSO3: To handle large data sets and carry out data analysis using software and programming language.
PSO4: To teach a wide range of statistical skills, including problem-solving, project work and presentation so as enable to take prominent roles in a wide spectrum of employment and research.
PSO5: To understand and meet the requirements of the government and non-government sectors in terms of professionally conducting surveys and data analysis. These methods will be beneficial in helping students develop employment skills.

Examination Pattern

Internal Examination

1. One written Test of 20 Marks (15 Marks (Very Short+ Short+ Long Questions) +5 Marks Quiz).
2. Five Marks for Class performance/Attendance.

External Examination: Written Examination of 75 Marks of 3 Hours Duration.

External Examination Pattern

Unit-I: Attempt all Five questions. Each question carries 3 Marks.
Unit-II: Attempt any Two out of Three questions. Each question carries 7.5 Marks.
Unit-III: Attempt any Three out of Five questions. Each question carries 15 Marks.

LIST OF PAPERS IN ALL FOUR SEMESTERS

Year	Semester	Course Code	Course Title	Core Compulsory/ Elective/Value Added	Theory/ Practical/ Project	Credits	Internal Marks	External Marks (Min Marks)	Total Marks	Minimum Marks (Int+Ext)	Teaching Hours
Year-4 as per NEP-2020/ Year-I	Semester- VII as per NEP-2020/ Semester-I	0720601	Real Analysis and Linear Algebra	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0720602	Distribution Theory	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0720603	Survey Sampling	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0720604	Programming with R	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0720680	Practical Lab (Based on the contents of Theory Courses)	Core Compulsory	Practical	4	25	75(25)	100	40	60
		0720665	Research Project-I	Core Compulsory	Project	4	25	75(30)	100	40	60
		0720650	Basic Statistics	Minor-Elective & Value added (for other faculty)	Theory	4	25	75(25)	100	40	60
	Semester- VIII as per NEP-2020/ Semester-II	0820601	Probability Theory	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0820602	Statistical Inference-I	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0820603	Linear Models and Experimental Designs	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0820604	**Any One of the following:** (i) Statistical Quality Control and Reliability Theory	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0820605	(ii) Regression Analysis		Theory	4	25	75(25)	100	40	60
		0820680	Practical Lab (Based on the contents of Theory Courses)	Core Compulsory	Practical	4	25	75(25)	100	40	60
		0820665	Research Project-II	Core Compulsory	Project	4	25	75(30)	100	40	60
			Project-I + Project-II	Core Compulsory	Viva-Voce	8	50	150(60)	200	80	120
		0820650	Applied Statistics	Minor-Elective & Value added (for other faculty)	Theory	4	25	75(25)	100	40	60

Year-5 as per NEP-2020/ Year-II	**Semester- IX as per NEP-2020/ Semester-III**	0920601	Statistical Inference-II	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0920602	Economic Statistics	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0920603	**Any Two of the following:** (i) Operations Research	Core Compulsory	Theory	4	25	75(25)	100	40	60
		0920604	(ii) Official Statistics		Theory	4	25	75(25)	100	40	60
		0920605	(iii) Bayesian Inference		Theory	4	25	75(25)	100	40	60
		0920606	(iv) Advanced Experimental Designs		Theory	4	25	75(25)	100	40	60
		0920680	Practical Lab (based on the contents of Theory Courses)	Core Compulsory	Practical	4	25	75(25)	100	40	60
		0920665	Research Project-III	Core Compulsory	Project	4	25	75(30)	100	40	60
	Semester- X as per NEP-2020/ Semester-IV	1020601	Multivariate Analysis	Core Compulsory		4	25	75(25)	100	40	60
		1020602	**Any Three of the following:** (i) Stochastic Process and Survival Analysis	Core Compulsory	Theory	4	25	75(25)	100	40	60
		1020603	(ii) Econometrics		Theory	4	25	75(25)	100	40	60
		1020604	(iii) Biostatistics		Theory	4	25	75(25)	100	40	60
		1020605	(iv) Advanced Operations Research		Theory	4	25	75(25)	100	40	60
		1020606	(v) Computer Intensive Statistical Methods		Theory	4	25	75(25)	100	40	60
		1020607	(vi) Population Studies		Theory	4	25	75(25)	100	40	60
		1020680	Practical Lab (Based on the contents of Theory Courses)	Core Compulsory	Practical	4	25	75(25)	100	40	60
		1020665	Research Project-IV	Core Compulsory	Project	4	25	75(30)	100	40	60
			Project-III + Project-IV	Core Compulsory	Viva-Voce	8	50	150(60)	200	80	120

Post Graduate Diploma in Research (PGDR) in Statistics as per NEP 2020/Pre-Ph.D. Course work in Statistics Guidelines (Effective from 2022-23)

		Course Code	**Course Title**	**Core Compulsory**	**Theory/ Practical / Project**	**Credits**	**Internal Marks**	**External Marks (Min Marks)**	**Total Marks**	**Minimum Marks (Int+Ext)**	**Teaching Hours**
Year-6 as per NEP-2020/ Year-I	**Semester- XI as per NEP-2020/ Semester- I**	1120601	Research Methodology	Core Compulsory	Theory	4	25	75	100	55	60
		1120602	Advanced Classical and Bayesian Inference	Core Compulsory	Theory	6	25	75	100	55	60
		1120603	Reliability Theory	Core Compulsory	Theory	6	25	75	100	55	60
		1120665	Research Project	Qualifying							

DETAILED SYLLABUS

Programme/Class: M.Sc.	**Year:** First	**Semester:** First
Subject: Statistics		
Course Code: 0720601	**Course Title:** Real Analysis and Linear Algebra	

Course Objectives: To introduce the students with the fundamentals of real analysis and linear algebra.

Course Outcomes: On successful completion of this course, students will be able to:

- Understand the convergence of sequence and series of real-valued functions.
- Know the concepts of continuity of real-valued functions and to differentiate between pointwise and uniform convergence.
- Understand the rank of a matrix, characteristic roots and vectors of a matrix, and properties of symmetric matrices.
- Understand the concepts of vector space and subspaces.

Credits: 4	**Core:** Compulsory
Max. Marks:	**Minimum Passing Marks:**

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Elementary set theory, Finite, Countable and uncountable sets, Introductions to real numbers, Open and closed intervals (rectangles), Sequences of real numbers, their convergence, Limit superior, Limit inferior.	**7**
II	Cauchy sequences and their convergence. Monotonic sequences and their limits. Limits of standard sequences. Infinite series and its convergence. Tests for convergence and divergence of a series.	**8**
III	Sequences and series of functions, Pointwise and uniform convergence, Continuity, Uniform continuity and differentiability of real-valued functions, Maxima-minima of functions, Functions of several variables, Multiple integrals, Change of order of variables in multiple integration.	**12**
IV	Algebra of matrices, Standard matrices (Symmetric and Skew Symmetric matrices, Hermitian and Skew Hermitian matrices, Orthogonal and Unitary matrices, Idempotent and Nilpotent matrices).	**12**
V	Determinant and trace of a matrix, Adjoint and inverse of a matrix and related properties. Rank of a matrix, Row-rank, Column-rank, Standard theorems on ranks.	**6**
VI	System of linear equations, Row reduction and echelon forms, Eigenvalues and eigenvectors, Cayley-Hamilton theorem.	**5**
VII	Vector spaces, Subspaces, Linear dependence and independence, Dimension and basis of a vector space, Orthogonal and orthonormal vectors, Gram–Schmidt orthogonalization process, and Orthonormal basis.	**10**

Suggested Readings:

1. Apostol, T.M. (1985). Mathematical Analysis. Narosa Indian Edn.

2. Shanti Narain (2005). A Course in Mathematical Analysis. S. Chand and Company, Pvt. Ltd.
3. Bartle, R.G. and D.R.Sherbert (2011). Introduction to Real Analysis, 4th Edition. Wiley.
4. Rudin, W. (2013). Principles of Mathematical Analysis, 3rd Edition. McGraw Hill.
5. Biswas, S. (2012). A Textbook of Matrix Algebra, 3rd Edition. PHI Learning.
6. Biswas, S. (1997). A Text Book of Matrix Algebra, 2nd ed., New Age International Publishers.
7. Golub, G.H. and C.F.Van Loan (1989). Matrix Computations, 2nd ed., John Hopkins University Press, Baltimore-London.
8. Hadley, G. (2002). Linear Algebra. Narosa Publishing House (Reprint).
9. Robinson, D.J.S. (1991). A Course in Linear Algebra with Applications. World Scientific, Singapore.
10. Searle, S.R. (1982). Matrix Algebra useful for Statistics. John Wiley and Sons.
11. Strang, G. (1980). Linear Algebra and its Application, 2nd ed., Academic Press, London New York.

Programme/Class: M.Sc.	**Year:** First	**Semester:** First
Subject: Statistics		
Course Code: 0720602	**Course Title:** Distribution Theory	

Course Objectives: To provide a thorough theoretical knowledge and understanding of different types of distributions (symmetric, compound, truncated, mixture etc.) and characterization of all the useful discrete and continuous distributions.

Course Outcomes: On successful completion of this course, students will be able to:

- Understand different types of distributions and their application in real-life problems.
- Describe the distinguishing features of various probability distributions.
- Work with sampling distributions (central and non-central Chi-square, t and F distributions).

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Joint, marginal, and conditional distributions of two-dimensional and multi-dimensional random variables, Distributions of transformations of random variable.	**10**
II	Symmetric distributions, Truncated distributions, Compound distributions, Mixture distributions, Exponential family of distributions.	**8**
III	Characterization and applications of discrete probability distributions: Binomial, Poisson, Multinomial, Hyper-geometric, Geometric, Negative binomial.	**8**
IV	Continuous probability distributions: Uniform, Normal (univariate and bivariate), Exponential (univariate and bivariate), Laplace, Cauchy, Beta, Gamma, Weibull and lognormal distributions.	**12**
V	Sampling distributions, elementary ideas of non-central distributions: non-central Chi-square, t and F distributions and their properties.	**8**
VI	Distributions of quadratic forms. Approximating distributions of sample moments, limiting moment generating function.	**7**
VII	Order statistics, their distribution and properties, Joint and marginal distributions of order statistics, Extreme values and their asymptotic distributions (statement only) with applications.	**7**

Suggested Readings:

1. Rohatgi, V. K. (1976). An Introduction to Probability Theory and Mathematical Statistics. Wiley, New York.
2. Hogg, Robert V. and Allen T. Craig (1995). Introduction to Mathematical Statistics 5th edition. Englewood Hills, New Jersey.
3. Johnson, Norman L., Samuel Kotz, and Narayanaswamy Balakrishnan (1995). Continuous Univariate Distributions. John Wiley and Sons.
4. Goon, A.M., M.K. Gupta and B. Das Gupta (2011). Fundamentals of Statistics, Vol. I. The World Press, Kolkata.
5. Mood, A.M., F.A. Graybill and D.C. Boes (19963). Introduction to the Theory of Statistics. Mc-Graw Hill Book Company, Inc., New York.
6. Goon A.M., M.K. Gupta and B. Dasgupta (2002). Fundamentals of Statistics, Vol. I and II, 8th Edn. The World Press, Kolkata.
7. Hogg, R.V., E.A. Tanis and J.M. Rao (2009). Probability and Statistical Inference, 7th Edition. Pearson Education, New Delhi.

Programme/Class: M.Sc.	**Year:** First	**Semester:** First
Subject: Statistics		
Course Code: 0720603	**Course Title:** Survey Sampling	

Course Objectives: To acquaint the students about the need and merits of sampling over census and the implementation of various sampling schemes along with their merits, demerits and comparisons in appropriate practical situations.

Course Outcomes: On successful completion of this course, students will be able to:

- Understand the distinctive features of different sampling schemes and related estimation problems.
- Learn about various approaches to estimate the parameters; with and without replacement sampling scheme, sampling with varying probability of selection.
- Learn the practical applications of the various sampling techniques in real-life situations.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Concept of population and sample, Need for sampling, Complete enumeration versus sampling, Basic concepts in sampling, Sampling and Non-sampling errors, Basic principles of sample surveys, Sampling and non-sampling errors.	**8**
II	Types of sampling, Non-probability and probability samplings. Simple random sampling, Sampling from finite populations with and without replacement, Unbiased estimation and confidence intervals for population mean and total, Simple random sampling of attributes.	**6**
III	Stratified random sampling, Reasons for stratification, Estimation of population mean and its variance, Construction of strata, Proportional and optimum allocation, Variances of estimates under different allocations, Comparison with simple random sampling for fixed sample size.	**10**
IV	Ratio, product and regression methods of estimation, Estimation of population mean, Evaluation of bias and variance to the first order of	**8**

	approximation, and Comparison with simple random sampling.	
V	Systematic Sampling (when population size (N) is an integer multiple of sampling size (n), Estimation of population mean and variance of this estimate, Comparison with simple random sampling. Cluster Sampling, Estimates of mean and its variance for equal and unequal clusters, Efficiency in terms of the intra-class correlation coefficient. Concept of multistage sampling and its application.	**10**
VI	Two-stage sampling with equal number of second stage units, Estimation of population mean and total, Double sampling for stratification.	**10**
VII	Sampling with probability proportional to size (with and without replacement method), Des Raj estimator, Horvitz-Thomson's estimator, Mid-Zuno Sen sampling scheme.	**8**

Suggested Readings:

1. Cochran, William G. (1977). Sampling Techniques, 3rd Edition. John Wiley and Sons.
2. Sukhatma, P.V.and B.V. Sukhatme (1970). Sampling Theory with Applications, 2nd Edition. Iowa State University Press.
3. Murthy, M.N. (1977). Sampling Theory and Methods. Statistical Publishing Society,Calcutta.
4. Singh, Daroga, and F.S. Chaudhary (1986). Theory and Analysis of Sample Survey Designs. John Wiley and Sons.
5. Mukhopadhyay, Parimal (2008). Theory and Methods of Survey Sampling. PHI Learning Pvt. Ltd.
6. Des Raj and P. Chandhok (1998). Sample Survey Theory. Narosa Publishing House.
7. Sampat, S. (2001). Sampling Theory and Methods. Narosa Publishing House.

Programme/Class: M.Sc.	**Year:** First	**Semester:** First
Subject: Statistics		
Course Code: 0720604	**Course Title:** Programming with R	
Course Objectives: To introduce the students with the fundamentals of R-language and its applications. **Course Outcomes:** On successful completion of this course, students will be able to: • Effectively visualize and summarize the data using R-language. • Carry out data analysis using R-language • Interpret the results of statistical analysis.		
Credits: 4	**Core:** Compulsory	
Max. Marks: …..	**Minimum Passing Marks:** ….	
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0		

Unit	**Topics**	**No. of Lectures**
I	Introduction to R, Advantages of R over other programming languages, R Studio: R Command prompt, R Script file, comments, handling packages in R, Installing an R package.	**6**
II	R Data types: Vectors, Lists, Matrices, Arrays, Factors, Data frame, R variables, Variable assignment, Data types of variable, Finding variable ls(), Deleting variables, R Operators: Arithmetic operators, Relational operators, Logical operator, Assignment operators, Miscellaneous operators.	**8**
III	R Decision making: if statement, if – else statement, if – else if statement, switch statement, R loops: repeat loop, while loop, for loop, Loop control statement: break statement, next statement.	**8**

IV	Loading and handling Data in R: Getting and setting the working directory – getwd(), setwd(), dir(), R-CSV Files - Input as a CSV file, Reading a CSV File, Analyzing the CSV File: summary(), min(), max(), range(), mean(), median(), apply() - Writing into a CSV File, R -Excel file, Reading the excel file.	**10**
V	Data visualization using R (both two and three dimensions); Tables, charts and plots. Visualising Measures of Central Tendency, Variation, and Shape. Histogram, Boxplot, Scatter plot, Pareto diagrams, pie chart, stem and leaf display.	**8**
VI	Statistical computing with R: Univariate and Multivariate statistics; Mean, Median, Variance, Covariance, Correlation, Linear regression. One and two sample t-tests, Analysis of Variance (ANOVA), Chi-square tests: goodness of fit, Contingency tables, Non-parametric tests, Distribution functions in R.	**10**
VII	Time series Analysis with R: Creating and manipulating a time series, Components of a time series, auto-correlation and partial correlation function, testing for stationarity, Forecasting using Autoregression (AR), Moving Average (MA),Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA) models.	**10**

Suggested Readings:

1. Sandip Rakshit (2017). R Programming for Beginners. McGraw Hill Education India.
2. Seema Acharya (2018). Data Analytics using R. McGraw Hill Education, India.
3. Gardener, M. (2012). Beginning R: The Statistical Programming Language, Wiley Publications.
4. Braun W. J. and D. J.Murdoch (2007). A First Course in Statistical Programming with R. Cambridge University Press, New York
5. Dalgaard, Peter (2020). Introductory statistics with R. Springer.
6. Alain F. Zuur, Elena N. Ieno and Erik Meesters (2009). A Beginner's Guide to R. Springer.
7. Michael J. Crawley (2005). Statistics: An Introduction using R. Wiley.
8. Maria L. Rizzo (2008). Statistical Computing with R. Chapman and Hall/CRC, Boca Raton, FL.
9. Chambers, John M. (2008). Software for Data Analysis: Programming with R, Vol. 2. New York: Springer.

Programme/Class: M.Sc.	**Year:** First	**Semester:** First
Subject: Statistics		
Course Code: 0720680	**Course Title:** Practical Lab	
Course Objectives: To introduce the students with the fundamentals of R-language and its applications practically. **Course Outcomes:** On successful completion of this course, students will be able to: • Learn the practical knowledge of the model fitting approach. • Solve real life problems with the knowledge of R-Software.		
Credits: 4	**Core:** Compulsory	
Max. Marks: …..	**Minimum Passing Marks:** ….	
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 0-0-4		
Topics		**No. of Lectures**

	1. Problems based on fitting of Distributions. 2. Problems based on Simple random sampling, Stratified random sampling. 3. Problems based on Ratio and regression methods of estimation. 4. Problems on data analysis with R. 5. Problems on data handling etc with R.		60
	Suggested Continuous Evaluation method: (25 Marks) Continuous Internal Evaluation shall be based on Practical File/Record, Class Activities and Overall performance. The marks shall be as follows:		
	Practical File/Record **Class Interaction** **Report Preparation/ Presentation**	**10 Marks** **5 Marks** **10 Marks**	
Suggested Practical Examination Evaluation Methods: (75 Marks) Practical Examination Evaluation shall be based on Viva-voce and Practical Exercises. The marks shall be as follows:			
Practical Exercise (1 Major) (1 x 25 Marks) **Practical Exercise (2 Minors) (2 x 15 Marks)** **Viva-voce**		**25 Marks** **30 Marks** **20 Marks**	

Programme/Class: M.Sc.	**Year:** First	**Semester:** First
Subject: Statistics		
Course Code: 0720650	**Course Title:** Basic Statistics	

Course Objectives: To introduce the students of other faculty with the fundamental knowledge of statistics so that they can understand the tools of statistics in depth.

Course Outcomes: On successful completion of this course, students will be able to:

- Learn the basic tools of Statistics and apply them in real life problems.
- Understand the application of central tendency as It condenses the data set down to one representative value when working with large amounts of data.
- Predict the output, forecasting the data etc. through Regression analysis.
- Measure the strength of relationship between variables through correlation.

Credits: 4	**Core:** Minor-Open Elective
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Concept of primary and secondary data, Methods of collection of data, Types of data: Qualitative and quantitative data, Discrete and continuous data,	**8**
II	Different types of scales: Nominal, Ordinal, Ratio and Interval, Classification and tabulation of data, Diagrammatic representation of data: Bar diagrams, Pie chart, Histogram, Frequency curve and Ogive.	**8**
III	Measures of Central tendency: Mean, Median, Mode and Quartiles, Percentiles, Merits, demerits and applications of measures of central tendencies, Box plot.	**10**
IV	Measures of Dispersion: Range, Mean deviation, Standard deviation and Variance, Coefficient of variation, Merits, demerits and applications of Measures of Dispersion, Skewness, Kurtosis.	**10**

V	Bivariate data, Scatter diagram, Covariance, Pearson's coefficient of Correlation, Regression analysis, Regression lines and Regression coefficients, Method of least squares.	**10**
VI	Sample space, Mutually exclusive and Equally likely events, Independent events, Definitions of probability, Additive and Multiplicative laws of probability, Conditional probability.	**8**
VII	Definition of random variable, its types, Concepts of Probability mass function (pmf) and Probability density function (pdf) with examples.	**6**

Suggested Readings:

1. Gupta, S.C. and V.K. Kapoor (2008). Fundamentals of Applied Statistics. S. Chand and Sons.
2. Snedecor, G. W. and W.G. Cochran (1989). Statistical Methods, 8th Edition, Wiley.
3. Das, N.G. (2012). Statistical Methods, Vol I and II. Tata McGraw Hill
4. Bhat, B. R., T. Srivenkataramana and K. S.Rao Madhava (1996). Statistics: A Beginner's Text, Vol. I and II. New Age International (P) Ltd.

Programme/Class: M.Sc.	**Year:** First	**Semester:** Second
Subject: Statistics		
Course Code: 0820601	**Course Title:** Probability Theory	

Course Objectives: To introduce students to formal probabilistic concepts that are required for a theoretical understanding of statistical concepts by paying special attention to applications of the measure theory in the probability theory.

Course Outcomes: On successful completion of this course, students will be able to:

- To work with probability measures, random variables and their distributions in an abstract framework.
- Prove and apply the convergence of a sequence of random variables.
- Understand the concept of independence of random variables, weak and strong laws of large numbers and central limit theorem.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Classes of Sets, Fields, Sigma-Fields, Minimal Sigma Field, Borel Sigma Field, Sequence of Sets, Lim sup and Lim inf of Sequence of Sets, Measure, Properties of a measure, Probability Measure.	**8**
II	Random experiment, Outcomes, Sample space, Events, Various definitions of probability, Laws of total and compound probability, Boole's inequality, Conditional probability, Independence of events, Bayes Theorem.	**8**
III	Random variable, Probability mass function (pmf), Probability density function (pdf), Cumulative distribution function (cdf), Expectation of a random variable, Properties of expectation.	**7**
IV	Moment generating function, Probability generating function, Characteristic function and its properties, Uniqueness theorem, Levy's continuity theorem.	**8**
V	Markov's, Chebychev's, Kolmogorov's, Minkowski's and Jenson's inequalities. Different modes of convergence (convergence in distribution, in probability, almost surely, and r^{th} mean) and their interrelations. Borel-Cantelli lemma and Borel 0-1 law.	**10**

VI	Weak law of large numbers (WLLN), Kolmogorov strong law of large numbers.	**10**
VII	Liapounoff's Central limit theorem for a sequence of independent random variables, Central limit theorem for independently and identically distributed random variables.	**9**

Suggested Readings:

1. Rohatgi, V. K. (1976). An Introduction to Probability Theory and Mathematical Statistics. Wiley, New York.
2. Mukhopadhyay, Parimal (2012). Theory of Probability. New Central Book Agency.
3. Bhat, B. R. (2014). Modern Probability Theory. Wiley Eastern Limited.
4. Pittman, J. (1993). Probability. Narosa Publishing House.
5. Mood, A. M., F. A. Graybill, and D. C. Boes (1963). Introduction to the Theory of Statistics. McGraw Hill Book Company, Inc., New York.
6. Ross, Sheldon M. (2014). Introduction to Probability Models. Academic Press.
7. Ash, Robert B. (2000). Probability and Measure Theory. Academic Press.
8. Hogg, R.V., J. McKean, and A.T. Craig (2013). Introduction to Mathematical Statistics, 7th Edition. Pearson.

Programme/Class: M.Sc.	**Year:** First	**Semester:** Second
Subject: Statistics		
Course Code: 0820602	**Course Title:** Statistical Inference-I	

Course Objectives: To provide a systematic account of point estimation and hypothesis testing, together with their applications.

Course Outcomes: On successful completion of this course the students will be able to:

- Understand the various estimation and testing procedures to deal with real-life problems.
- Learn about the Fisher Information, lower bounds to variance of estimators, and MVUE.
- Understand the concept of the Neyman-Pearson fundamental lemma and UMP test.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Characteristics of a good estimator, Consistency, Unbiasedness, Efficiency, Sufficiency and Completeness, Sufficiency when the range of variate depends on the parameter, Characterization of distribution admitting sufficient statistics, Factorization theorem.	**8**
II	Minimum variance bound estimator, Cramer-Rao Inequality, Extension of Cramer-Rao inequality for multi-parameter case, Bhattacharya bounds.	**8**
III	Rao-Blackwell theorem, Lehman-Scheffe's theorem, Uniformly Minimum Variance Unbiased Estimator (UMVUE).	**8**
IV	Estimation methods of Maximum likelihood, Minimum chi-square, Moment and Least squares. Optimal properties of maximum likelihood estimator, Existence of a Best Asymptotically Normal (BAN) estimate, Hazor Bazar theorem.	**8**
V	Null, alternative, simple and composite hypotheses, Concept of Critical	**10**

	Region, Critical function, Two-type of Errors, Power of a Test, Level of Significance, p-value, Neyman-Pearson Lemma and its Generalization.	
VI	Uniformly Most Powerful (UMP) Test, 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 distributions with Monotone Likelihood Ratio (MLR) property.	**10**
VII	Randomized Tests, Uniformly Most Powerful unbiased (UMPU) test, Types A, A_1 Critical Regions, Likelihood Ratio Test.	**8**

Suggested Readings:

1. Kale, B.K. (1999). A First Course on Parametric Inference. Narosa Publishing House.
2. Dudewitz, E.J. and S.N. Mishra (1988). Modern Mathematical Statistics. John Wiley.
3. Rao, C.R. (1973). Linear Statistical Inference and its Applications. Wiley Eastern.
4. Lehman E.L (1988). Theory of point estimation. John Wiley.
5. Lehmann, E.L. (1986). Testing Statistical Hypotheses. Student Editions.
6. Zacks, S. (1971). Theory of Statistical Inference. Wiley, New York.
7. Rohatgi, V.K. (1988). An Introduction to Probability and Mathematical Statistics. Wiley Eastern, New Delhi.
8. Ferguson, T.S. (1967). Mathematical Statistics. Academic Press.
9. Gupta, S.C. and V.K. Kapoor (2000). Fundamentals of Mathematical Statistics, 10th Edition. Sultan Chand and Sons.
10. Bartoszynski, R. and M.N. Bugaj (2007). Probability and Statistical Inference. John Wiley and Sons.

Programme/Class: M.Sc.	**Year:** First	**Semester:** Second
Subject: Statistics		
Course Code: 0820603	**Course Title:** Linear Models and Experimental Designs	

Course Objectives: To provide the students the ability to understand the design and conduct experiments, as well as to analyze and interpret data.

Course Outcomes: On successful completion of this course the students will be able to

- Understand the concepts of linear estimation.
- Know about the theory and applications of ANOVA, ANCOVA.
- Apply and analyse various forms of Designs i.e., CRD, RBD, LSD etc. to various fields of applications.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Gauss-Markov linear models, Estimable functions, Error and estimation space, Normal equations and least square estimators, Properties of least square estimators.	**8**
II	Generalized inverse of a matrix and solution of normal equations, Variances and covariances of least square estimators, Best linear unbiased estimator (BLUE).	**7**
III	One-way and two-way classifications, fixed, random and mixed effects models. Analysis of variance for one-way and two-way classifications.	**6**
IV	Multiple comparison tests due to Tukey, Scheffe and Student-Newmann-Keul-Duncan, Analysis of Covariance for a one-way layout with concomitant variable.	**9**

V	The basic principle of experimental design (Randomization, Replication and Local control), Complete analysis and layout of completely randomized design (CRD), Randomized block design (RBD) and Latin square design (LSD), and Missing plot technique.	**10**
VI	Factorial experiments (2^n, 3^2, 3^3), Complete and Partial, and balanced confounding.	**8**
VII	Incomplete block designs, Balanced Incomplete Block Designs (BIBD) with parametric relations and analysis under a fixed effect model, Split Plot Design and Strip Plot Design.	**12**

Suggested Readings:

1. Joshi, D.D. (1987). Linear Estimation and Design of Experiments. John Wiley.
2. Bapot, R.B. Linear Algebra and Linear Model. Cambridge University Press.
3. Das, M.N. and N.C. Giri (1986). Design and Analysis of Experiments, 2nd Edition. Wiley.
4. Cochran W.G. and G.M. Cox (1959). Experimental Design. Asia Publishing House.
5. Kempthorne, O. (1965). The Design and Analysis of Experiments. John Wiley.
6. Federer, W.T. (1955). Experimental Design: Theory and Applications. Oxford and IBH (P) Ltd., New Delhi.
7. Montgomery, D.C. (2008). Design and Analysis of Experiments. John Wiley.
8. John, P.W.M. (1971). Statistical Design and Analysis of Experiments. Macmillan Co., New York.

Programme/Class: M.Sc.	**Year:** First	**Semester:** Second
Subject: Statistics		
Course Code: 0820604	**Course Title:** Statistical Quality Control and Reliability Theory	

Course Objectives: To equip the students with the concepts of Statistical Quality Control, Quality Assurance and Performance Analysis.

Course Outcomes: On successful completion of this course the students will be able to:

- Understand the techniques of Statistical Quality control and application of these techniques to improve the quality of production.
- Apply reliability tools to improve the system's reliability.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Statistical process and product control, Quality of a product, Need for quality control, Basic concept of process control, Process capability and Product control.	**6**
II	General theory of control charts, Causes of variation in quality, Control limits, Charts for variables: R, ($\bar{X}$, R), ($\bar{X}$, σ)charts., Charts for attributes: p-chart, np-chart, C-chart.	**7**
III	Sampling inspection v/s 100% inspection. Introduction to acceptance sampling, Rejection and Rectification types, Consumer's risk, Producer's risk, Acceptance sampling plans for attributes: Single, Double, Multiple and Sequential sampling plans and their properties, OC, AOQL, ASN and ATI curves.	**8**

IV	Reliability, its concept and measures, Components and systems, Coherent systems, and Reliability of coherent systems. Life-distributions, Reliability function, Failure rate, Hazard rate, Bath-tub failure rate curve, Reliability estimation with complete and censored sample.	**10**
V	Lifetime distributions: Exponential, Weibull, Gamma, Normal, Bivariate exponential distributions. Estimation of parameters and tests in these models.	**10**
VI	System configurations: Series, Parallel, Parallel-series, Series-parallel, Mixed, k-out of- n and related configurations. Mean time to system failure (MTSF) and mean time between failures.	**9**
VII	Concept of redundancy, different types of redundancy and its use in reliability improvement. Analysis of reliability and MTSF of n-unit standby redundancy, Analysis of non-identical unit series system with constant failure and repair rates, two identical unit active and passive redundant systems with constant failure and repair rates.	**10**

Suggested Readings:

1. Barlow R.F. and F. Proschan (1965). Mathematical Theory of Reliability. John Wiley, New York.
2. Sri Nath, L.S. Mathematical Theory of Reliability. Affiliated East West Press Pvt. Ltd.
3. Balagurusamy, E. (1984). Reliability Engineering. Tata McGraw Hill Publishing Company Ltd, New Delhi.
4. Bowkder A.K. and H.P. Goode. Sampling Inspection by Variables. McGraw Hill Edition.
5. Montgomery, D.C. (2009). Introduction to Statistical Quality Control. Wiley India Pvt. Ltd.
6. Goon, A.M., M.K. Gupta and B. Das Gupta (2002). Fundamentals of Statistics, Vol. 1 and 2. The World Press, Kolkata.
7. Sinha, S.K. (1986). Reliability and Life Testing. Wiley Eastern.
8. Lawless, J.F. (2003). Statistical Models and Methods for Life Data. Wiley.
9. Marshall, A.W. and I. Olkin (2007). Life Distributions. Springer.

Programme/Class: M.Sc.	**Year:** First	**Semester:** Second
Subject: Statistics		
Course Code: 0820605	**Course Title:** Regression Analysis	

Course Objectives: To develop the theoretical foundation of regression models and understand fundamental concepts of regression analysis.

Course Outcomes: On successful completion of this course, students will be able to:

- Understand simple and multiple linear regression models with their applications
- Learn model adequacy using classical diagnostics, awareness of potential problems (outliers, etc.) and application of remedies to deal with them.
- Understand the basic concepts of logistic, Poisson and generalized linear models.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Simple linear regression model, Least squares estimation of parameters, Hypothesis testing on the slope and intercept, Interval estimation in simple linear regression, Prediction of new observations, Coefficient of determination, Estimation by method of maximum likelihood.	**10**

II	Multiple linear regression models, Estimation of the model parameters, Hypothesis testing in multiple linear regression. Confidence intervals in multiple regression, Coefficient of determination and Adjusted R^2.	**8**
III	Model Adequacy: Checking of linearity between study and explanatory variable, Residual Analysis, Detection and treatment of outliers, Residual plots. The predicted residual error sum of squares (PRESS) statistic.	**8**
IV	Test for lack of fit of the regression model, Transformation and Weighting to Correct Model Inadequacies, Variance stabilizing transformations, Transformations to linearize the model, Analytical methods for selecting a transformation on study variable.	**10**
V	Generalized and weighted least square estimation, Polynomial Regression Models, Polynomial models in one variable, Orthogonal Polynomials, Piecewise polynomial (Splines), Variable Selection and Model Building, Incorrect model specifications, Evaluation of subset regression model, Computational techniques for variable selection.	**10**
VI	Logistic and Poisson regression models: Introduction, Linear predictor and link functions, logit, probit, odds ratio, maximum likelihood estimation, test of hypothesis.	**6**
VII	Generalized linear models: Exponential family of distribution, Linear predictors and link functions, Maximum likelihood estimation of GLM. Prediction and confidence interval with GLM.	**8**

Suggested Readings:

1. Montgomery, D.C., E.A. Peck, and G.G. Vining (2015). Introduction to Linear Regression Analysis, 5th Edition. Wiley.
2. Rao, C.R. (2009). Linear Statistical Inference and its Applications, 2nd Edition. Wiley.
3. Draper, N.R. and H. Smith (2011). Applied Regression Analysis, 3rd Edition. Wiley.
4. Chatterjee, S. and A.S. Hadi (2012). Regression Analysis by Example, 5th Edition. Wiley.
5. Fox, J. and S. Weisberg (2019). An R Companion to Applied Regression, 3rd Edition. Sage Publications.
6. P. McCullough and J.A. Nelder (1989). Generalized Linear Models, 2nd Ed., Chapman and Hall.

Programme/Class: M.Sc.	**Year:** First	**Semester:** Second
Subject: Statistics		
Course Code: 0820680	**Course Title:** Practical Lab	
Course Objectives: To introduce the students with the Estimation of parameters techniques, testing of hypotheses, Analysis of variance techniques and Experimental designs. **Course Outcomes:** On successful completion of this course, students will be able to: • Solve day to day problems with knowledge of Statistical Inference. • Learn the application of Design of experiments in real life scenario.		
Credits: 4	**Core:** Compulsory	
Max. Marks: …..	**Minimum Passing Marks:** ….	
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 0-0-4		
Topics		**No. of Lectures**

	1. Problems on Estimation of Parameters and 2. Problems based on Testing of Hypothesis. 3. Problems based on One-way and Two-way ANOVA. 4. Problems based on CRD, RBD and LSD. 5. Problems based on Factorial Experiments. 6. Problems based on Control charts. 7. Problems based on Regression analysis.	**60**
	Suggested Continuous Evaluation method: (25 Marks) Continuous Internal Evaluation shall be based on Practical File/Record, Class Activities and Overall performance. The marks shall be as follows: **Practical File/Record** — **10 Marks** **Class Interaction** — **5 Marks** **Report Preparation/ Presentation** — **10 Marks** **Suggested Practical Examination Evaluation Methods: (75 Marks)** Practical Examination Evaluation shall be based on Viva-voce and Practical Exercises. The marks shall be as follows: **Practical Exercise (1 Major) (1 x 25 Marks)** — **25 Marks** **Practical Exercise (2 Minors) (2 x 15 Marks)** — **30 Marks** **Viva-voce** — **20 Marks**	

Programme/Class: M.Sc.	**Year:** First	**Semester:** Second
Subject: Statistics		
Course Code: 0820650	**Course Title:** Applied Statistics	
Course Objectives: To introduce the students with the knowledge of Applied statistics to enhance their skills. **Course Outcomes:** On successful completion of this course, students will be able to: • Learn about different types of statistical distributions. • Have an understanding of the various tests of significance. • Learn different types of Designs of experiments with their applications in practical life.		
Credits: 4	**Core:** Minor-Open Elective	
Max. Marks: …..	**Minimum Passing Marks:** ….	
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0		

Unit	Topics	No. of Lectures
I	Discrete distributions: Binomial, Poisson with their properties and applications, Uniform distribution.	**8**
II	Continuous distributions: Uniform, Normal, Exponential distributions with their properties and applications.	**8**
III	Concept of population and sample, Need for sampling, Complete enumeration versus sampling, Basic concepts in sampling, Sampling and Non-sampling errors, Basic principles of sample surveys, Sampling and non-sampling errors. Types of sampling, Non-probability and probability samplings.	**12**
IV	Statistical process and product control, Quality of a product, Need for quality control, Basic concept of process control, Process capability and Product control, General theory of control charts, Causes of variation in quality.	**8**
V	Testing of Hypothesis, Simple, Composite, Null and Alternative hypothesis,	**8**

	two types of errors, Critical region, and Power of a test, p-value.	
VI	Tests of significance based on t-test, F-test and Chi-square test of Goodness of fit.	**6**
VII	Analysis of One way and two way classification, Principles of Design of Experiments, Completely randomized design (CRD), Randomized block design (RBD) and Latin square design (LSD) with their applications.	**10**

Suggested Readings:

1. Gupta, S.C. and V.K. Kapoor (2000). Fundamentals of Mathematical Statistics. S. Chand and Sons.
2. Gupta, S.C. and V.K. Kapoor (2008). Fundamentals of Applied Statistics. S. Chand and Sons
3. Snedecor, G. W. and W.G. Cochran (1989). Statistical Methods, 8th Edition, Wiley.
4. Goon, A.M., M.K. Gupta and B. Das Gupta (2002). Fundamentals of Statistics, Vol. 2. The World Press, Kolkata.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Third
Subject: Statistics		
Course Code: 0920601	**Course Title:** Statistical Inference-II	

Course Objectives: To provide deeper knowledge of inferential statistics such as sequential estimation, OC and ASN functions, loss and risk functions, one, two and k-samples non-parametric tests.

Course Outcomes: On successful completion of this course, students will be able to:

- Have an understanding of interval estimation and its relationship with the testing of hypothesis.
- Learn the basic concepts of nonparametric techniques.
- Understand the sequential probability ratio test and its application.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Interval estimation, Confidence interval, One sided lower and upper confidence intervals, Two-sided confidence intervals, Pivotal method of constructing Confidence Interval, General method of constructing large sample confidence intervals with examples.	**10**
II	Shortest length Confidence Intervals, and Relationship with the Testing of Hypothesis	**5**
III	Probability Integral Transformation, Estimation of Quantiles, Construction of Confidence Interval for Population Quantiles.	**10**
IV	Non-parametric or distribution-free methods, Tests for location, Sign test for one and two-sample problems, Wilcoxon's signed rank test.	**10**
V	Test for Randomness, Median test, Mann-Whitney test, Kolmogorov-Smrinov test for one and two samples.	**7**
VI	The sequential probability ratio test (SPRT) and its application to Binomial, Poisson, Normal, and other simple cases.	**10**
VII	Operating characteristic (OC) function of SPRT, Average sample number (ASN) function and their application, termination theorem of SPRT with probability one, Wald's fundamental identity and its uses	**8**

Suggested Readings:

1. Gupta, S.C. and V.K. Kapoor (2008). Fundamentals of Mathematical Statistics, S.Chand and Sons.
2. Wald, A. Sequential Analysis. John Wiley and Sons New York
3. Gibbons, J.D. (1971). Non-parametric Statistical Inference. McGraw Hill International Edition.
4. Siegel, S. (1988). Non-Parametric Statistics for the Behavioral Sciences. McGraw Hill Edition.
5. Mood, A.M., F.A. Graybill and D.C. Boes (2011). Introduction to the Theory of Statistics, 3rd Edition. Tata McGraw Hill Pub. Co. Ltd.
6. Goon, A.M., M.K. Gupta and B. Das Gupta (2002). Fundamentals of Statistics, Vol. 2. The World Press, Kolkata.
7. Rohatgi, V.K. (1984). An Introduction to Probability Theory and Mathematical Statistics. Wiley Eastern Ltd. New Delhi.
8. Lehman, E.L. (1983). Theory of Point Estimation. John Wiley.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Third
Subject: Statistics		
Course Code: 0920602	**Course Title:** Economic Statistics	

Course Objectives: To make the students conversant with economic statistics through time series analysis and demand analysis and with various techniques used in summarization and analysis of data related to demographic and vital events.

Course Outcomes: On successful completion of this course the students will be able to

- Have an understanding of various models and components of time series analysis for forecasting purposes.
- Know the basic concepts of demand analysis.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Time Series Analysis: Object, Decomposition, Components of a time series, Additive and multiplicative models, Examples of time series, Trend component, Polynomial, Logistic, Gompertz and log-normal trend functions, Smoothing by moving average.	**10**
II	Spencer's formulae, Slutsky-Yule effect, Variate difference method, Measurement of seasonal and cyclical components.	**7**
III	Periodogram and Harmonic Analysis, auto-correlation and partial correlation function, testing for stationarity, Forecasting using Autoregression (AR), Moving Average (MA), Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA) models.	**10**
IV	Demand Analysis: Laws of Demand and Supply, Price and Supply Elasticity of Demand, Income Elasticity of Demand, Utility Function.	**10**
V	Methods of determining Demand and Supply Curves from Family Budget and Time Series Date, Leontief's Method, Pigou's Method, Engel Curve and its different forms, Pareto's Law of Income Distribution.	**8**
VI	Index Numbers: Criteria of a good index number, Price relatives and quantity or volume relatives, Link and chain relatives' composition of index numbers; Laspeyre's, Paasche's, Marshal Edgeworth and Fisher index numbers, tests for index number.	**8**

VII	Chain base index number, Construction of index numbers of wholesale and consumer prices.	**7**

Suggested Readings:

1. Gupta, S.C. and V.K. Kapoor (2008). Fundamentals of Applied Statistics. S. Chand and Sons.
2. Box, G.E.P. and G.M. Jenkins (1976). Time series analysis-Forecasting and Control. Holden-day.
3. Kendall, M.G. and A. Stuart (1966). The Advanced Theory of Statistics, Vol. 3. Charles Griffin, London.
4. Kendall, Sir Maurice and J.K. Ord (1990). Time Series, 3rd Edition. Edward Arnold.
5. Wald, H. Demand Analysis. The Academic Press
6. Johnston, J. (1984). Econometric Methods. McGraw Hill, New York.
7. Gujarati, D. N. (2004). Basic Econometrics. Tata McGraw Hill.
8. Maddala, G.S. and K. Lahiri (2012). Introduction to Econometrics. Wiley.
9. Madnani, G.M.K. (2015). Introduction to Econometrics: Principles and Applications. Oxford & IBH Publishing Co Pvt.Ltd.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Third
Subject: Statistics		
Course Code: 0920603	**Course Title:** Operations Research	
Course Objectives: To provide the ideas of formulating mathematical modeling and their optimum solution in the context of practical problems belonging to Govt./Pvt. sectors. **Course Outcomes:** On successful completion of this course the students will be able to • Have an understanding of various models and components of time series analysis for forecasting purposes. • Know the basic concepts of demand analysis.		
Credits: 4	**Core:** Compulsory	
Max. Marks: …..	**Minimum Passing Marks:** ….	
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0		

Unit	Topics	No. of Lectures
I	Definition and scope of operations research (OR), Modelling in O.R., Applications of O.R. Mathematical formulation of Linear Programming Problem (LPP), Graphical method to an LPP.	**8**
II	Convex set, convex combination and extreme points, simplex method to solve an LPP with slack, surplus and artificial variables, construction of dual of an LPP.	**7**
III	Mathematical formulation of a Transportation problem, Northwest corner rule, Unit cost penalty method and method of Matrix minima, Optimality test, Unbalanced transportation problem, Degeneracy in transportation problems.	**10**
IV	Assignment problems, formulation of these problems and their solutions, unbalanced assignment problems.	**6**
V	Inventory control: Problems of inventory and the various costs associated with inventory control, EOQ models with uniform/non-uniform rate of demands when shortages are allowed and not allowed while the replenishment of inventory is instantaneous, Newspaper Boy problem.	**10**

VI	Queueing Theory, Introduction of the queuing system, Various components of a queueing system, Pure Birth Process; Pure Death Process, Birth and Death Process, M/M/1, M/M/1 (Generalized), M/M/1/FCFS/K/∞, M/M/C, Erlang's loss model, Machine repair problem.	**10**
VII	Game theory: Criteria of pure and mixed strategies, pay-off matrix and saddle point, Solution of Zero sum two person games-2×2, 2×n, m×2, and m×n by minimax and maximin techniques, arithmetic method, algebraic method, dominance principle, sub-game method and linear programming techniques.	**9**

Suggested Readings:

1. Taha, H.A. (1982). Operations Research: An Introduction. MacMillan Publishing Company, New York.
2. Hillier, F.S. and G.J. Leiberman (1962). Introduction to Operations Research. Holden Day.
3. Kanti Swaroop, P.K. Gupta and M.M. Singh (1985). Operations Research. Sultan Chand and Sons.
4. Mckuisey, J.C.C. (1952). Introduction to the Theory of Games. McGraw Hill.
5. Saaty, T.L. (1961). Elements of Queuing Theory with Applications. McGraw Hill.
6. Gross, D. and C.M. Harris (1974). Fundamentals of Queuing Theory. John Wiley.
7. Mckinsey, J.C.C. (1952). Introduction to the Theory of Games. McGraw Hill.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Third
Subject: Statistics		
Course Code: 0920604	**Course Title:** Official Statistics	

Course Objectives: To provide students with knowledge of national and international statistical systems.

Course Outcomes: : On successful completion of this course, the students will be able to

- Know the overall statistical systems in the country.
- Understanding of roles and responsibilities of major statistical organisations.
- Know methodologies and agencies involved in the population census and important sample surveys.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Introduction to Indian and International statistical systems: Role, function and activities of central and state statistical organizations, Organization of large-scale sample surveys, Roles, Responsibilities, Important activities, Collection and compilation of data, Analysis and dissemination, Agencies Involved.	**10**
II	National Statistical Organization: Vision and Mission, NSSO and CSO; Roles and responsibilities; Important activities, Publications etc.	**8**
III	National Statistical Commission: Need, Constitution, Its role, functions etc; Legal Acts/ Provisions/ Support for Official Statistics; Important Acts.	**8**
IV	National Income/GDP, Purchasing Power Parity: Needs, Methods of Calculation, Usages, Reliability, Draw Backs; Indicators relating to energy, Environment, Gender, Industry, Social Statistics and trade.	**8**
V	Sector-wise Statistics: Health, Education, Women and Child etc. Surveys and Census by NSSO, Labour Bureau, RBI etc. Indicators, Agencies and usage and Principal publications containing such Statistics, National Family Health Survey, Socio-Economic Indicators, Gender Awareness/Statistics, Important Surveys.	**10**

VI	Population Census: History, Need, Data Collected, Periodicity, Methods of data collection, Dissemination, Agencies involved.	**8**
VII	Agricultural Census: Its objectives, Methods of collection, Agricultural data, Its features, Utility of Census, Merit and Demerits of Agricultural Census, Principal, Publications of Agricultural Data.	**8**

Suggested Readings:

1. Basic Statistics Relating to the Indian Economy, CSO, 1990.
2. Guide to Official Statistics, CSO, 1999.
3. Statistical System in India, CSO, 1995.
4. V.G. Panse (1964). Estimation of Crop Yields, FAO (Rome).
5. Monthly Statistics of Foreign Trade in India, DGCIS, Calcutta and other Govt. Publications.
6. Principles and accommodation of National Population Censuses, UNESCO.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Third
Subject: Statistics		
Course Code: 0920605	**Course Title:** Bayesian Statistics	

Course Objectives: To include the methods of estimation and testing of hypotheses in the Bayesian framework.

Course Outcomes: On successful completion of this course, students will be able to:

- Obtain Bayes estimators for population parameters.
- Develop tests and confidence intervals for population parameters.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Decision theory: Loss function, Risk function, Randomised and Non-randomised decision rules, Minimax and Bayes decision rules, Bayes and Minimax estimators.	**8**
II	An outline of Bayesian framework, Bayes Theorem, Types of priors, Conjugate prior, proper and improper priors, subjective prior etc., Methods of obtaining priors.	**8**
III	Types of loss functions, Squared error loss function (SELF), Absolute error loss, O-1 loss, Asymmetric loss functions such as LINEX and Entropy loss functions, Mixture of loss functions.	**10**
IV	Computation of posterior distribution, Bayesian calculations, Monte Carlo Technique, Approximation methods, Empirical method, Gibbs sampler.	**10**
V	Credible Intervals, Highest Posterior Density Regions, Interpretation of the Confidence Coefficient of an Interval and its Comparison with the Coefficient of Classical Confidence intervals.	**10**
VI	Specification of the Appropriate Form of the Prior Distribution for a Bayesian Testing of Hypothesis Problem.	**8**
VII	Prior Odds, Posterior Odds, Bayes Factor, Bayesian Information Criterion (BIC).	**6**

Suggested Readings:

1. Goon A.M., M.K. Gupta and B. Das Gupta. An Outline of Statistical Theory, Vol. 2. The World Press Private Ltd. Calcutta.

2. Rohatgi, V.K. (1984). An Introduction to Probability Theory and Mathematical Statistics. Wiley Eastern Ltd, New Delhi.
3. Hogg R.V. and A.T. Craig (1971). Introduction to Mathematical Statistics. Princeton University Press.
4. Wald, A. Statistical Decision Functions. John Wiley and Sons, New York.
5. Ferguson T.S. Mathematical Statistics- A Decision-Theoretic Approach. Academic Press.
6. Robert, C.P. and G. Casella (1999). Monte Carlo Statistical Methods. Springer Verlag.
7. Berger, J.O. Statistical Decision Theory and Bayesian Analysis. Springer Series.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Third
Subject: Statistics		
Course Code: 0920606	**Course Title:** Advanced Experimental Designs	
Course Objectives: To provide the knowledge of the construction and analysis of various applied designs such as BIBD, Factorial designs etc. **Course Outcomes: :** On successful completion of this course the students will be able to • Lean about MOLS, BIBD, PBIBD, Factorial etc. • Apply these designs in real-life scenario.		
Credits: 4	**Core:** Compulsory	
Max. Marks: …..	**Minimum Passing Marks:** ….	
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0		

Unit	Topics	No. of Lectures
I	Elementary Theory of groups, Elements of projective and Euclidean Geometries, Galois field.	**6**
II	Construction of (i) Mutually orthogonal Latin squares (MOLS) (ii) Hyper Graeco Latin Squares (iii) Incomplete Block Designs (Balanced and Partially Balanced) (iv) Totally and partially Confounded symmetric factorial designs.	**10**
III	Incomplete Block Design, Balanced Incomplete Block Design (BIBD), Partially Balanced Incomplete Block Design (PBIBD), Analysis of BIBD with recovery of inter-block information.	**10**
IV	Factorial experiments, factorial effects, Testing of significance of factorial effects of 2^2, 2^3 and 3^2experiments, Yates procedure for estimating the effects.	**10**
V	Analysis of factorial designs (2x4, 3x3, 3^2), Square and rectangular lattice designs.	**7**
VI	Complete and partial confounding, construction of symmetrical confounded factorial experiments.	**10**
VII	Response Surfaces, Fractional replication in case of 2^n and 3^n types, Analysis of group of experiments.	**7**

Suggested Readings:

1. Dey, A. (1986). Theory of Block Designs. John Wiley and Sons.
2. Dean, A. and D. Voss (1999). Design and Analysis of Experiments. Springer.
3. Das, M.N. and N.C. Giri (1986). Design and Analysis of Experiments. Wiley Eastern.
4. Joshi, D.D. (1987). Linear Estimation and Design of Experiments. New Age International Pvt Ltd.
5. Montgomery, D.C. (2005). Design and Analysis of Experiments, 6th Edition. John Wiley and Sons.
6. Giri, N.C. (1986). Analysis of Variance. South Asian Publishers.
7. Scheffe, H. (1959). The Analysis of Variance. John Wiley.

Programme/Class: M.Sc.	**Year:** First	**Semester:** Third
Subject: Statistics		
Course Code: 0920680	**Course Title:** Practical Lab	

Course Objectives: To introduce the students with the interval estimation technique, Non-parametric tests, Sequential analysis and Economic Statistics.

Course Outcomes: On successful completion of this course, students will be able to:

- Learn how to estimate parameter though Interval estimation.
- Perform Non-parametric tests on real datasets.
- Perform Economic statistics on real datasets.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 0-0-4

	Topics		**No. of Lectures**
	1. Problems based on Interval estimation. 2. Problems based on Non-parametric tests. 3. Problem based on Sequential test. 4. Problems based on Economic Statistics. 5. Problems based on Advanced experimental designs.		**60**
	Suggested Continuous Evaluation method: (25 Marks) Continuous Internal Evaluation shall be based on Practical File/Record, Class Activities and Overall performance. The marks shall be as follows:		
	Practical File/Record **Class Interaction** **Report Preparation/ Presentation**	**10 Marks** **5 Marks** **10 Marks**	
	Suggested Practical Examination Evaluation Methods: (75 Marks) Practical Examination Evaluation shall be based on Viva-voce and Practical Exercises. The marks shall be as follows:		
	Practical Exercise (1 Major) (1 x 25 Marks) **Practical Exercise (2 Minors) (2 x 15 Marks)** **Viva-voce**	**25 Marks** **30 Marks** **20 Marks**	

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Fourth
Subject: Statistics		
Course Code:1020601	**Course Title:** Multivariate Analysis	

Course Objectives: To introduce students to the analysis of observations on several correlated random variables for a number of individuals and their practical applicability.

Course Outcomes: : On successful completion of this course, the students will be able to

- Account for important theorems and concepts in multivariate analysis.
- Understand and apply the statistical estimation and testing procedures in the multivariate scenario.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	**Topics**	**No. of Lectures**

I	Multivariate normal distribution, Distribution of random vector Y=CX when C is a non-singular matrix, Distribution of p-variate random vector Z=DX when D is a qxp matrix of rank q(< p), characterisation of p-variate normal distribution.	**8**
II	Marginal and conditional distributions of a sub-vector of a normally distributed random vector, Moment generating function, Characteristic function of a normally distributed random vector, Reproductive property of a p-variate normal distribution.	**8**
III	Maximum likelihood estimators of Mean vector and covariance matrix, Distribution of sample mean vector. Inference concerning the mean vector when the covariance matrix is known. Distribution of the Quadratic Forms.	**8**
IV	Hotelling's T^2 and its sampling distribution, application in test on mean vector for one and more multivariate normal population and also on equality of components of a mean vector in multivariate normal population. Mahalanobis' D^2 statistic.	**8**
V	Wishart matrix, its distribution and properties, distribution of sample generalized variance, null and non-null distribution of multiple correlation coefficients.	**8**
VI	Multiple regression Analysis, Multiple and Partial Correlations and their Estimation, Distributions of Partial and Multiple Correlation Coefficients in Samples from Multivariate Normal Populations in the Null cases only.	**10**
VII	Problem of Classification into one of the two categories, Procedures of Classification into one of two populations with known density functions, Priori probabilities and costs of misclassification, Best Regions of Classification into one of two known Multivariate Normal Populations, Fisher's Discriminant function.	**10**

Suggested Readings:

1. Anderson, T.W. (1982). Multivariate Analysis. Wiley Eastern Ltd., New Delhi.
2. Giri, N.C. (1977). Multivariate Statistical Inference. Academic Press.
3. Morrison, D.F. (1976). Multivariate Statistical Methods, 2nd Edition. McGraw Hill.
4. Kshirasagar, A.M. (1972). Multivariate Analysis. Marcel Decker.
5. Muirhead, R. (1982). Aspects of Multivariate Statistical Theory. J. Wiley.
6. Rao, C.R. (1973). Linear Statistical Inference and its Applications, 2nd Edition. Wiley.
7. Johnson, R.A. and D.W.Wichern (2015). Applied Multivariate Statistical Analysis, Sixth Edition,
8. Pearson Education India.
9. Hardle, W.K. and Z. Hlavka (2015). Multivariate Statistics, Springer.
10. Anderson, T.W. (2003). An Introduction to Multivariate Statistical Analysis, Third Edition, Wiley.
11. Singh, B.M. (2004). Multivariate statistical analysis, South Asian Publishers.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Fourth
Subject: Statistics		
Course Code: 1020602	**Course Title:** Stochastic Process and Survival Analysis	
Course Objectives: To study the different types of stochastic process, random walk, and renewal theory with their wide applicability in social science, economics and management sciences. **Course Outcomes: :** On successful completion of this course the students will be able to: • Know about various Stochastic Processes and applications of these processes in real-life scenarios. • Apply various life testing models in real-life situations.		
Credits: 4	**Core:** Compulsory	

Max. Marks: …..	Minimum Passing Marks: ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Stochastic Processes: Introduction, classification according to state space and time domain. Countable state Markov chains, transition probability matrix.	**10**
II	Chapman-Kolmogorov equations, calculation of n-step transition probabilities and their limits, Stationary distribution. Transient Markov chain, Random walk and Gambler's ruin problem.	**10**
III	Continuous-time Markov Processes: Poisson process and related distributions, generalizations of Poisson process, simple birth-process, simple death-process, simple birth-death process, linear birth-death process. First passage time distribution.	**10**
V	Concepts of survival function, failure rate or hazard function, mean residual life and its properties.	**10**
VI	Different types of censoring *viz.*, left (type I), right (type II) with real-life examples.	**8**
VII	Estimation of mean survival time and variance of the estimator for type I and type II censored data, Estimation of survival parameters with Exponential, Weibull, Normal, Log-normal and Gamma models for failure data	**12**

Suggested Readings:

1. Sheldon, M. Ross (1996). Stochastic Processes, 2nd Edition. Wiley Eastern.
2. Biswas, S. (1995). Applied Stochastic Processes, Wiley.
3. Bailey, Norman T. (1965). The Elements of Stochastic Processes, John Wiley and Sons, Inc.
4. Doob, J.L. (1953). Stochastic Processes. Wiley New York.
5. Kale, B.K. (1999). A First Course on Parametric Inference, Narosa publishing House.
6. Medhi, J. (1982). Stochastic Processes, Ist Edition. New Age International (P) Ltd.
7. Sinha, S.K. (1986). Reliability and Life Testing. Wiley Eastern Ltd, Delhi, India.
8. Parzen, E. (1962). Stochastic Processes, Holden-Day.
9. Cox, D. R. and D. Oakes (1984). Analysis of Survival Data. Chapman and Hall, New York.

Programme/Class: M.Sc.	Year: Second	Semester: Fourth
Subject: Statistics		
Course Code: 1020603	**Course Title:** Econometrics	

Course Objectives: To introduce the students to econometrics and its applications in different fields.

Course Outcomes: On successful completion of this course the students will be able to:

- Perform analyses of economic data based on a broad knowledge of the linear regression model.
- To specify assumptions, formulate and estimate appropriate models, interpret the results and test their statistical significance.

Credits: 4	Core: Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures

I	Introduction to econometrics. A review of least squares and maximum likelihood estimation methods of parameters in classical linear regression model and their properties.	**8**
II	The general linear model (GLM) and its extensions, Ordinary least squares (OLS) estimation and prediction, Generalized least squares (GLS) estimation and prediction.	**8**
III	Autocorrelation, its consequences, Autoregressive process tests for autocorrelation, Durbin Watson test.	**8**
IV	Multicollinearity problem, its implications and tools for handling the problem, ridge regression.	**8**
V	Heteroskedasticity, consequences and tests for it, estimation procedures under heteroskedastic disturbances, Bartlett's test, Goldfelf Quandt test, Dummy Variable Models.	**10**
VI	Linear regression and stochastic regression, instrumental variable estimation, Errors in variables, autoregressive linear regression, lagged variables, distributed lag models, estimation of lags by OLS method, Koyck's geometric lag model.	**10**
VII	Simultaneous linear equations model and its generalization, identification problem, restrictions on structural parameters, rank and order conditions. Estimation in simultaneous equations model, recursive systems, 2 SLS estimators.	**8**

Suggested Readings:

1. Gujrati, D.N. and D.C.Porter (2017). Basic Econometrics, 6th Edition. McGraw Hill.
2. Maddala, G.S. and K. Lahiri (2010). Introduction to Econometrics, 4th Edition. Wiley.
3. Greene, W.H. (2012). Econometric Analysis, 7th Edition. Pearson.
4. Studenmund, A.H. and B.K.Johnson (2017). Using Econometrics: A Practical Guide, 7th Edition. Pearson.
5. Johnston, J. (1984). Econometric Methods, McGraw Hill Kogakusha Ltd.
6. Judge, G.G., R, C.Hill, W.E.Griffiths, H. Lutkepohl and T.C. Lee. (1988). Introduction to the Theory and Practice of Econometrics, 2nd ed., John Wiley and Sons.
7. Kmenta, J. (1986). Elements of Econometrics, 2nd ed., Mac Millan.
8. Apte, P.G. (1990). Textbook of Econometrics. Tata McGraw Hill.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Fourth
Subject: Statistics		
Course Code: 1020604	**Course Title:** Biostatistics	
Course Objectives: To introduce the students with the application of statistical methods to medical, biological, epidemiological and health-related problems. **Course Outcomes: :** On successful completion of this course the students will be able to: • Know the techniques to summarize medical and health-related data. • Understand the basic principles of probability and how they relate to biostatistics.		
Credits: 4	**Core:** Compulsory	
Max. Marks: …..	**Minimum Passing Marks:** ….	
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0		
Unit	**Topics**	**No. of Lectures**

I	Measuring the occurrence of disease: Measures of morbidity - prevalence and incidence rate, Association between prevalence and incidence, Uses of prevalence and incidence, problems with incidence and prevalence measurements.	**8**
II	Clinical agreement, Kappa statistics, Mantel-Haenszel test, Intra-class correlation, Surveillance.	**7**
III	Assessing the validity and reliability of diagnostic and screening test, Validity of screening test – sensitivity, specificity, positive predictive value and negative predictive value.	**8**
IV	Reliability, Relationship between validity and reliability, ROC curve and its applications, Overall accuracy.	**7**
V	Issues in epidemiology, Association, Causation, Causal inference, Errors and bias, Confounding, Controlling confounding, Measurement of interactions, Generalizability.	**10**
VI	Estimating risk, Estimating association – absolute risk, relative risk, odds ratio, Estimating potential for prevention – attributable risk, Comparison of relative risk and attributable risk.	**10**
VII	Odds ratios for retrospective studies, Odds ratios approximating the prospective RR, Exact inference for odds ratio analysis of matched case-control data.	**10**

Suggested Readings:

1. Altman, D.G. (2006). Practical Statistics for Medical Research. London: Chapman and Hall.
2. Rosner, B. (2006). Fundamentals of Biostatistics.
3. Bonita, R., R. Beaglehole and T. Kjellstrom (2006). Basic Epidemiology, 2nd Edition. World Health Organization.
4. Gordis, L. (2004). Epidemiology, 3rd Edition. Philadelphia.
5. Dunn, G. and B. Everitt (1995). Clinical Biostatistics: An Introduction to Evidence-based Medicine. Edward Arnold.
6. Daniel, W.W. and C.L. Cross (2012). Biostatistics: A Foundation for Analysis in the Health Sciences, 10th Edition. Wiley.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Fourth
Subject: Statistics		
Course Code: 1020605	**Course Title:** Advanced Operations Research	
Course Objectives: To give students a firm foundation in the advanced optimization techniques for the solution of the problems covered in course contents. **Course Outcomes:** On successful completion of this course, the students will be able to: • Develop the ability to formulate fairly complex optimization problems in the context of practical problems.		
Credits: 4	**Core:** Compulsory	
Max. Marks: …..	**Minimum Passing Marks:** ….	
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0		
Unit	**Topics**	**No. of Lectures**

I	Integer Linear Programming: Concept of integer linear programming problems, Gomory's all IPP techniques, Branch and Bound method for solving IPP, Applications of IPP.	**8**
II	Quadratic Programming: Structure of quadratic programming, Kuhn-Tucker conditions, Wolfe's modified simplex and Beale's methods for solving a Q.P.	**8**
III	Replacement Problem: Replacement policy of items whose maintenance cost increases with time constant and varying scrap value.	**9**
IV	Revised Simplex Method: Standard forms for revised simplex method, Computational procedure for standard form-1 and standard form-2.	**8**
V	Job Sequencing : Assumptions, Solution of sequencing problems, Processing n jobs through two machines, Processing n jobs through three machines, Processing two jobs through n-machines, Processing n-jobs through n-machines.	**12**
VI	CPM-PERT: Development of CPM/PERT techniques, events and activities, application of CPM/PERT techniques.	**7**
VII	Network diagram representation, rules for drawing Network diagram, Critical Path Analysis, Project evaluation and review technique (PERT).Updating of the project, Resource allocation.	**8**

Suggested Readings:

1. Taha, H.A. (1982). Operations Research: An Introduction. MacMillan Publishing Company, New York.
2. Hillier, F.S. and G.J. Leiberman (1962). Introduction to Operations Research. Holden Day.
3. Kanti Swaroop, P.K.Gupta and M. M. Singh (1985). Operations Research. Sultan Chand and Sons.
4. Churchman, C.W., R.L. Ackoff and E.L.Arnoff (1957). Introduction to Operations Research. John Wiley.
5. Hadley G. and T.M. Whitin (1963). Analysis of Inventory Systems. Prentice Hall.
6. Starr, M. K. and D.W. Miller (1962). Inventory Control – Theory and Practice. Prentice Hall.
7. Shamblin, J.E. and G.T. Stevens (1974). Operations Research: A Fundamental Approach. McGraw Hill.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Fourth
Subject: Statistics		
Course Code: 1020606	**Course Title:** Computer Intensive Statistical Methods	

Course Objectives: To introduce students with statistical simulation, random number generation and variance reduction techniques.

Course Outcomes: On successful completion of this course the students will be able to:

- Understand the basic ideas of random number generation using different techniques.
- Learn theoretical methods and practicable techniques of statistical simulations.
- Understand how to apply Monte Carlo simulations and the EM algorithm.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Introduction and need of statistical simulation. Random number generation, requisites of a good random number, methods of random number generation such as linear congruential and mixed congruential.	**10**

II	Statistical tests for pseudo-random numbers. Methods of generating random variables such as inverse transform, composition and acceptance-rejection methods.	**10**
III	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.	**10**
IV	EM algorithm: applications to missing and incomplete data problems, mixture models. Smoothing with kernels, density estimation.	**7**
V	Simple nonparametric regression. Smoothing with kernels: density estimation, choice of kernels.	**8**
VI	Simulation based testing: simulating test statistics and power functions, permutation tests. Bootstrap methods: resampling paradigms, bias and standard errors, confidence intervals, bootstrapping in regression.	**8**
VII	Jack-knife and cross-validation: Jack-knife in sample surveys, cross-validation for tuning parameters.	**7**

Suggested Readings:

1. Rubinstein, R.Y. and D.P. Kroese (2008). Simulation and the Monte Carlo Method, Second Edition, Wiley.
2. Voss, J. (2014). An Introduction to Statistical Computing: A Simulation Approach. Wiley.
3. Ross, S.M. (2012). Simulation, Fifth Edition. Academic Press.
4. Thomopoulos, N.T. (2013). Essentials of Monte Carlo Simulation. Springer.
5. G.S. Fishman (1996). Monte Carlo: Concepts, Algorithms, and Applications. Springer.
6. M.A. Tanner (1996). Tools for Statistical Interference, Third edition. Springer.
7. B. Efron and R.J. Tibshirani (1993). An introduction to the Bootstrap. Chapman and Hall.
8. J. Shao and D. Tu (1995). Jack-knife and the Bootstrap. Springer Verlag.

Programme/Class: M.Sc.	**Year:** Second	**Semester:** Fourth
Subject: Statistics		
Course Code: 1020607	**Course Title:** Population Studies	
Course Objectives: To give students a firm foundation in the advanced optimization techniques for the solution of the problems covered in course contents. **Course Outcomes** On successful completion of this course, the students will be able to: • Develop the ability to formulate fairly complex optimization problems in the context of practical problems.		
Credits: 4	**Core:** Compulsory	
Max. Marks: …..	**Minimum Passing Marks:** ….	
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0		

Unit	**Topics**	**No. of Lectures**
I	Introduction to Demography, Sources of Demographic data, Limitations and uses of demographic data: Coverage and content errors in demographic data.	**8**
II	Use of balancing equations and Chandrasekharan-Deming formula to check the completeness of registration data, adjustment of age data- use of Whipple, Meyer and UN indices. Population composition, Age pyramid, Dependency ratio, Theory of demographic transition.	**10**

III	Measurement of Mortality: Crude death rate, Standardized death rates, Age-specific death rates, Infant Mortality rate, Definition, construction and uses of Life table, Complete and abridged life tables.	**8**
IV	Measurement of Fertility: Crude birth rate, General fertility rate, Age-specific birth rate, Total fertility rate, Gross reproduction rate, Net reproduction rate.	**6**
V	Rate of Population Growth: Arithmetic, Geometric and Exponential growth rates, Decadal growth rate Doubling time, Models for population growth and their fitting to population data. Stochastic models for population growth.	**12**
VI	Internal migration and its measurement, Concept of international migration, Net migration, Factors affecting population migration.	**6**
VII	Stable and quasi-stable populations, Stationary population, Population projection, Methods for population projection, Component method of population projection.	**10**

Suggested Readings:

1. Cox, P.R (1970). Demography. Cambridge University Press.
2. Benjamin, B. (1969). Demographic Analysis. George, Allen and Unwin.
3. Spiegelman, M. (1969). Introduction to Demographic Analysis, Harvard University
4. Biswas, S. (1988). Stochastic Processes in Demography and Applications, Wiley Eastern Ltd.
5. Keyfitz, N. (1971). Applied Mathematical Demography, Springer Verlag.
6. Office of Registrar General and Census Commissioner India (Ministry of Home Affairs)
7. Principles and accommodation of National Populations Census UNESCO.

Programme/Class: M.Sc.	**Year:** First	**Semester:** Fourth
Subject: Statistics		
Course Code: 1020680	**Course Title:** Practical Lab	

Course Objectives: To give hands-on instruction and experience in the selection, estimation, and interpretation of models for statistical modelling of data from real applications.

Course Outcomes: On successful completion of this course, students will be able to:

- Deal with the problems based on estimation of the mean vector and Variance-Covariance matrix using multivariate data.
- Deal with problems based on multiple correlation and regression analysis.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 0-0-4

	Topics	**No. of Lectures**
	1. Problems based on Multivariate Analysis (Code: 1020601) 2. Problems based on opted Courses (From Codes: 1020602 to 1020607)	**60**
	Suggested Continuous Evaluation method: (25 Marks) Continuous Internal Evaluation shall be based on Practical File/Record, Class Activities and Overall performance. The marks shall be as follows:	

	Practical File/Record **Class Interaction** **Report Preparation/ Presentation**	**10 Marks** **5 Marks** **10 Marks**	
	Suggested Practical Examination Evaluation Methods: (75 Marks) Practical Examination Evaluation shall be based on Viva-voce and Practical Exercises. The marks shall be as follows:		
	Practical Exercise (1 Major) (1 x 25 Marks) **Practical Exercise (2 Minors) (2 x 15 Marks)** **Viva-voce**	**25 Marks** **30 Marks** **20 Marks**	

Pre-Ph.D. Coursework Detailed Syllabus

Programme: Pre-Ph.D. Coursework	**Duration:** Six Months	**Semester:** First
Subject: Statistics		
Course Code: 1120601	**Course Title:** Research Methodology	

Course Objectives: The objective of the course is to make research students learn the scientific research methods and approaches.

Course Outcomes: On successful completion of this course, the students will be able to:

- Know basic principles of research, objectives of research, importance, types of research. The basics of computer application in our research work.
- The skills of research paper writing.
- The knowledge of citation, bibliography, h-index, plagiarism etc.
- The knowledge of INFLIBNET, e-journals, e-library, Scopus, database etc.

Credits: 4	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Perception & Definition of Research, Objectives & Motivations of Research, Importance of Research, Types of Research, Research Methods versus Methodology, Process of Research, Review of Literature, Formulation of the Research Problem, Sources and Identification of a Research Problem, Status of the Research Problem, Formulation of Hypothesis, Research Design, Ethics in Research.	**12**
II	Primary and Secondary data, Validity and Reliability of data collection procedures, data preparation, Exploratory data analysis, Parametric and Non-parametric tests, Correlation and regression analysis, ANOVA, Multivariate techniques, Scales of measurements, nominal, ordinal, interval and ratio scales, Errors in measurements, Validity and Reliability in measurement, Scale Construction Techniques..	**16**
III	Census versus Sample enumerations, objectives and principles of sampling, Types of sampling, Sampling and Non-sampling errors. Designing Questionnaire, Determination of the sample size.	**10**
IV	Computer Networking, Internet, Web Browsers, Search Engines, MS Word: Handling graphics, tables and charts, Formatting in MS-Word, MS Power point: Creating Slide Show, Screen Layout and Views, Applying Design Template, MS Excel: Features, Formulas and Functions, Number system, Computer codes, BCD Code, EBCDIC, ASCII, Computer Arithmetic.	**12**
V	Subject Classification Index, Citation, Citation Index, Impact factor, h-index, INFLIBNET, Introduction to Peer-Reviewed and Open Access Journals, e-Journals, e-Library, Web of Science, Scopus, Science-Direct etc.	**10**

Suggested Readings:

1. Kumar, R. (2011). Research Methodology A Step-by-Step Guide for Beginners, SAGE Inc.
2. Gupta, S. (2010). Research Methodology Methods and Statistical techniques. Deep & Deep publications
3. Gupta, S.P. (2014). Statistical Methods, Sultan Chand & Sons.
4. Creswell, W. (2018). Research Design, Qualitative, Quantitative and Mixed methods approaches, SAGE Inc.
5. Shortis, T. (2016). The Language of ICT: Information and Communication Technology, Taylor & Francis.

6. Anderson, J., B.H. Durston and M. Poole (1970). Thesis and Assignment Writing, Wiley Eastern. Ltd. New Delhi.
7. Kothari, C.R. and G. Garg (2014). Research Methodology: Methods and Techniques, 3rd Edition, New Age International Publishers.
8. Pannerselvan, R. (2006). Research Methodology, Prentice-Hall of India Pvt., New Delhi.

Programme: Pre-Ph.D. Coursework	**Duration:** Six Months	**Semester:** First
Subject: Statistics		
Course Code: 1120602	**Course Title:** Advanced Classical and Bayesian Inference	

Course Objectives: The objective of the course is to provide core knowledge of inference and useful distributions involved in estimating the parameters with their practical applicability and to equip the knowledge and understanding of applying Bayesian tools for predicting the parameters in real life situations.

Course Outcomes: On successful completion of this course, the students will be able to:

- Draw important conclusions regarding the population parameters.
- Obtain the classical point and interval estimates of the parameters of the lifetime distributions.
- Apply various techniques to test the goodness-of-fit.
- Compute posterior distribution under different priors and loss functions.
- Obtain the Bayesian point and interval estimates of the parameters of the lifetime distributions.
- Apply various techniques of simulation like Monte Carlo simulation and Markov Chain and Monte Carlo (MCMC).

Credits: 6	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Review of Consistency, Unbiasedness, Efficiency, Sufficiency and completeness, Crammer-Rao inequality and its applications, Rao-Blackwell and Lehman-Scheffe's theorems, Uniformly Minimum Variance Unbiased Estimation (UMVUE).	**12**
II	Review of Maximum likelihood estimation, Method of moments, Least square estimation, Concept of censoring, Different types of censoring schemes: Type I and Type II censoring, Progressive censoring, Random censoring, Maximum likelihood and moment estimation under different Censoring schemes, Asymptotic confidence interval.	**10**
III	Goodness-of-fit techniques, Classical goodness-of-fit plots: Histogram and density plots, Empirical cumulative distribution function, P-P plot, Q-Q plot, Goodness-of-fit criteria: Negative likelihood function, AIC and BIC criteria, Goodness-of-fit statistics: Kolmogorov-Smirnov (K-S) test, Cramer-Von Mises test and Anderson-Darling test.	**12**
IV	Bayesian Approach: Types of priors, Methods of obtaining priors, Types of loss functions, Risk function, Computation of posterior distribution under different priors and Loss functions, Empirical Bayes estimation, Highest posterior density (HPD) Credible intervals.	**14**
V	Monte Carlo integration, Importance sampling, Accept-reject method, Markov Chain and Monte Carlo (MCMC) method, Metropolis algorithm, Metropolis-Hastings algorithm, Gibbs sampling.	**12**

Suggested Readings:

1. Kale, B.K. (1999). A First Course on Parametric Inference, Narosa Publishing Company.
2. Sinha, S.K. (1998). Bayesian Estimation, New Age Publication.

3. Rohatgi, V. K. and A.K. Md. Ehsanes Saleh (2000). An Introduction to Probability and Statistics, Second Edition, Wiley Eastern Ltd.
4. Gelman, Andrew (2004). Bayesian Data Analysis. CRC Press.
5. Balagurusamy, E. (1984). Reliability Engineering, Tata McGraw Hill Education Private Limited.
6. Gentle, James E. (2003). Random Number Generation and Monte Carlo Methods, Springer.
7. Robert, C.P. and G. Casella (2010). Monte Carlo Statistical methods, Springer, New York.
8. Lawless, J.F. (2003). Statistical Models and Methods for Lifetime Data, Wiley.
9. Balakrishnan, N. and E. Cramer (2014). Art of Progressive Censoring, Birkhauser, Boston, Mass, USA.
10. Balakrishnan, N. and R. Aggarwal (2000). Progressive Censoring: Theory, Methods and Applications, Birkhauser, Boston, Mass, USA.

Programme: Pre-Ph.D. Coursework	**Duration:** Six Months	**Semester:** First
Subject: Statistics		
Course Code: 1120603	**Course Title:** Reliability Theory	

Course Objectives: The objective of the course is to understand the concept of the reliability and its various function, different system configurations, methods of reliability improvements with their practical aspects.

Course Outcomes: On successful completion of this course, the students will be able to:

- Understand the concept of reliability, Markov process, renewal process, semi-Markov process.
- Estimate reliability functions for different lifetime distribution.
- Describe various forms of hazard function.
- Evaluate reliability for simple and complex systems.
- Use the techniques of improving and estimating the reliability in day to day real existing engineering systems.

Credits: 6	**Core:** Compulsory
Max. Marks: …..	**Minimum Passing Marks:** ….

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
I	Laplace and Laplace- Stieltjes transforms, their properties, Definition of Stochastic Process, Specification of Stochastic Process, Definition and examples of Markov Process and Markov Chain, Transition Matrix, Poisson Process, Renewal Process, Semi-Markov Process, Definition and examples of Non-Markovian Process.	**10**
II	Definition of Reliability, Basic functions in Reliability (Reliability Function, Cumulative failure distribution function, Failure density function, Hazard rate) and their Relationships, Bathtub Curve, Pointwise and steady state availabilities, Interval availability and Interval reliability, Mean time to system failure (MSTF) and mean time between failures, Mean Residual Life, Mean Past Lifetime,	**12**
III	Constant, linearly increasing and non-linear increasing hazard models, Normal, gamma, lognormal and truncated normal failure laws, Estimation of reliability functions from failure data	**12**
IV	Reliability evaluation of a Series and Parallel Systems, Reliability of k-out-of-n System, Expression of Reliability for bridge configuration.	**12**
V	Various types of redundancies and their reliability comparison, System maintenance and system repair under different repair disciplines, various types of priority redundant systems. Analysis of simple two unit reparable system models with constant failure and repair rates.	**14**

Suggested Readings:

1. Sinha, S.K. (1986). Reliability and Life Testing, Wiley Eastern Ltd.
2. Mann,N., E. Schafer and Singapurwalla (1974). Methods for Statistical Analysis of Reliability and Life Data, Wiley.
3. Billinton, R. and Ronald N. Allan (1983). Reliability Evaluation of Engineering Systems: Concepts and Techniques, Plenum Press New York and London.
4. Charles, E. Ebeling (2000). An Introduction to Reliability and Maintainability engineering, Tata McGraw Hill Education Private Limited.
5. Balagurusamy, E. (1984). Reliability Engineering, Tata McGraw Hill Education Private Limited.
6. Srinath, L.S. (1975). Concepts in reliability with an introduction to Maintainability and Availability, Affiliated East-West Press Pvt. Ltd.
7. Medhi, J. (2011). Stochastic Processes, New Age International (P) Limited Publishers.
8. Sinha S.K. (1982). Reliability and Life Testing, Wiley Eastern Limited.