Karmaveer Bhaurao Patil University, Satara

Syllabus for

M.Sc. I Statistics

under

Faculty of Science and Technology

(As per NEP 2020)

(With effect from the academic year 2024-25)

Preamble

The goal of the syllabus is to make the study of Statistics popular and interesting among the students for job achievements as well as higher studies.

The syllabus is prepared after discussion at length with a number of faculty members of the subject and experts from industries and research fields. The units of the syllabus are well defined, taking into consideration the level and capacity of students.

Eligibility: B. Sc. with Statistics as principal subject.

General Objectives of the Course:

1. The students are expected to understand the principles, concepts and recent developments in the Statistics.
2. To enhance student sense of enthusiasm for Statistics and to involve them in an intellectually stimulating experience of learning in a supportive environment.
3. The practical course is framed in relevance with the theory courses to improve the understanding of the various concepts in Statistics.

Other features:

1. **Library:**

   Reference books and Textbooks, Journals and Periodicals, Reference Books for Advanced studies are available.

2. **Specific equipment's in laboratory:**

   60 Computers, LCD Projector, Visualizer, Smart board etc.

3. **Laboratory Software's:**

   1. SAS 2. SPSS 3. R-Software.

   4. MINITAB 5. Python

1. **Title:** M. Sc. (Statistics)
2. **Year of Implementation:** The syllabus will be implemented from June, 2024-25 onwards.
3. **Duration:** Two Years
4. **Pattern:** M. Sc. Statistics program has semester pattern and Choice Based Credit System. The program consists of 88 credits.
5. **Medium of instruction:** English

M.Sc. Part I

M.Sc. (Statistics) Semester – I

Course Code	Title of the course	Instruction Hrs/week	Marks- End Semester Exam	Marks- Internal Assessment	Credits
MST 411	Mathematical Statistics	4	60	40	4
MST 412	Estimation Theory	4	60	40	4
MST 413	Optimization Technique	4	60	40	4
MST 414	1. Sampling Theory	2	30	20	2
	2. Population Studies	2	30	20	
MST-415	Research Methodology	4	60	40	4
MSP 416	Practical-I	2	30	20	2
MSP 417	Practical-II	2	30	20	2
Total Credits of Sem-I					**22**

M.Sc. (Statistics) Semester – II

Course Code	Title of the course	Instruction Hrs/week	Marks- End Semester Exam	Marks- Internal Assessment	Credits
MST 421	Probability Theory	4	60	40	4
MST 422	Theory of Testing of Hypotheses	4	60	40	4
MST 423	Regression Analysis	4	60	40	4
MST 424	1. Linear Model and Design of Experiment	2	30	20	2
	2. Computational Statistics	2	30	20	
MSP 426	Practical-III	2	30	20	2
MSP 427	Practical-IV	2	30	20	2
RM – II	Research Project	4			4
Total Credits of Sem-II					**22**

M.Sc. -I

Evaluation Structure

Theory

Assessment Category	Internal Evaluation					ESE	Total Marks	Credit
	CCE-I	CCE-II	Mid Sem	Activity	Total			
Theory Paper of 4 Credit (Mandatory)	10	10	10	10	40	60	100	4
Theory Paper of 2 Credit (Elective)	5	5	5	5	20	30	50	2

Practical

Assessment Category	Internal Evaluation	ESE	Total Marks	Credit
	Journal/Viva/Activity			
Practical Paper of 2 Credit	20	30	50	2

6. Syllabus

M. Sc. Part-I (Semester-I)

MST-411: Mathematical Statistics (Credits: 04)

Course Objectives: Students will be able to understand,

1. Basic properties of the field of real numbers,
2. Series of real numbers and convergence, continuity, differentiability of real-valued functions.
3. The basic concepts of linear algebra and solving systems of linear equations.
4. Vectors and basic vector operations, eigenvalues and eigenvectors, quadratic forms etc.

Credits (Total Credits 4)	**SEMESTER – I MST-411 Mathematical Statistics**	**No.of hours per unit**
Unit - I	**Basic Notion of Set theory and Sequence and series**	**(15)**
	1.1 Set of real numbers, countable and uncountable sets, countability of rationals and uncountability of the interval (0,1). 1.2 Supremum and Infimum of bounded sets, limit point of a set, open, closed, dense and compact sets. Bolzano-Weierstrass and Heine-Borel Theorems (Statements only). Applications of the theorems 1.3 Sequence of real numbers, convergence, divergence, Cauchy sequence, Convergence of bounded monotone sequence. Limit inferior and limit superior of the sequences. Series of real numbers, tests for convergence (without proof) test for absolute convergence, the convergence of sequences of non- negative terms.	
Unit - II		**(15)**
	1.1 Real valued function, continuous function, Uniform continuity of sequence of functions, Uniform convergence of series of functions with special emphasis on power series, radius of convergence. 1.2 Riemann, Riemann -Steltjes Integrals and their common properties. Integration by parts, 1.3 Fundamental theorem on calculus, mean value theorem, their applications in finding functional of distributions.	
Unit - III	**Vector Space and Basic of Matrices**	**(15)**
	3.1 Vector space, subspace, linear dependence and independence, basis, dimension of a vector space, example of vector spaces. **3.2** Null space, Inner product spaces, Gram- Schmidt orthogonalization process, Orthonormal basis, orthogonal projection of a vector, **3.3** Linear transformations, algebra of matrices, row and column spaces of a matrix, elementary operations and elementary matrices, rank and inverse of a matrix,Null space and nullity, partitioned matrices	
Unit - IV	**Matrices**	**(15)**
	4.1 Permutation matrix, reducible/ irreducible matrix, primitive / imprimitive matrix, idempotent matrix, 4.2 Solution of a system of homogenous and non-homogenous linear equations, theorem related to existence of solution and examples. 4.3 Characteristic roots and vectors of a matrix, algebraic and geometric multiplicities of a characteristic root, right and left characteristic vectors,	

	4.4 orthogonal property of characteristic vectors, Caley-Hamilton Theorem and applications. 4.5 Spectral decomposition of a real symmetric matrix, singular value decomposition, Choleskey decomposition, extreme of a quadratic form, simultaneous reduction of two quadratic forms.	

Course Outcomes: Students are able to:

1. Define and recognize the basic properties of the field of real numbers.
2. Define and recognize the series of real numbers and convergence.
3. Apply the theorem in a correct mathematical way.
4. Carry out matrix operations, including inverses and determinants.
5. Demonstrate understanding of the concepts of vector space and subspace.
6. Demonstrate understanding of linear independence, span, and basis.
7. Determine eigenvalues and eigenvectors and solve eigenvalue problems.
8. Apply principles of matrix algebra to linear transformations.
9. Solve systems of linear equations using multiple methods, including Gaussian elimination and matrix inversion..

BOOKS RECOMMENDED:

1. **Mathematical Analysis,** Malik S. C. & Arora S., Wiley Eastern Limited-IInd edition,1991.
2. **Methods of Real Analysis**,Goldberg R.R.Blais dell Publishing company, Newyork, U.S.A, 1964.
3. **Element of Real Analysis**, Bartle G.R., Wiley, 2nd edition,1976.
4. **Introduction to Real Analysis-John**, Bartle G.R.&Sherbert D.R., Wiley & Son Inc,2000.
5. **Principles of Real Analysis**, Royden, Mac million,1988.
6. **An Introduction to Linear Statistical Models Vol 1**, Graybill, F.A., Mc Graw-HillBook Company Inc,1961.
7. **Linear Algebra**, Hadely G., Narosa Publishing House,1962.
8. **Matrix Algebra from Statistics Perspective**, Harville D., Springer, 1997.
9. **Linear Algebra**, Rao A. R. and Bhimasankaram P. Hindustan Book Agency ,Second dition,200

M. Sc. Part-I (Semester-I)
MST-412: Estimation Theory (Credits: 04)

Course Objectives: Students will be able to,

1. Derive suitable point estimators of the parameters of the distribution of a random variable and give a measure of their precision.
2. Learn computational skills to implement various statistical inferential approaches.

Credits (Total Credits 4)	**SEMESTER – I MST-412 Estimation Theory**	**No.of hours per unit**
Unit - I		**(15)**
	Sufficiency principle, factorization theorem, minimal sufficiency, minimal sufficient partition ,construction of minimal sufficient statistics, minimal sufficient statistic for exponential family, power series family, curved exponential family, Pitman family. Completeness, bounded completeness, ancillary statistics, Basu's theorem and applications.	
Unit - II		**(15)**
	Problem of point estimation, unbiased estimators, minimum variance unbiased estimator, Rao- Blackwell theorem and Lehmann-Scheffe theorem and their uses. Necessary and sufficient condition for MVUE and their applications. Fisher information and information matrix, Cramer- Rao inequality, Chapmann-Robinson bounds, Bhattacharya bounds,their applications.	
Unit - III		**(15)**
	Method of maximum likelihood (MLE) and small sample properties of MLE, method of scoring and application to estimation in multinomial distribution. MLE in non-regular families. Other methods of estimation: method of moments, minimum Chi square. U-Statistics: one and two sample; U-Statistics theorem for one sample and two sample(statements only).	
Unit - IV		**(15)**
	The concept of prior distributions, various types of priors, non-informative, Jeffrey's, least favorable prior, posterior distribution; Posterior distribution conjugate family and standard examples of such families. Bayes estimation under squared error and absolute error loss functions.	

Course Outcomes: Students are able to

1. Understand the notion of parametric models, point estimation of the parameters of those models.
2. Obtain the sufficient statistic, minimal sufficient statistic, m.l.e., moment estimator of the parameter.
3. Understand the concept of MVUE, MVBUE, UMVUE.
4. Describe the concept of Bayesian inference and their real life applications.

BOOKS RECOMMENDED:

1. **Introduction to Probability Theory and Mathematical Statistics**, Rohatgi, V. K. and Saleh,A. K. MD. E., John Wiley & sons, 3rd Edition. 2015.
2. **Theory of Point Estimation,** Lehmann, E. L., John Wiley & sons,1983.

3. **Linear Statistical Inference and its Applications,** Rao, C. R., wiley, 2nd Edition,1973.
4. **Parametric Inference: An Introduction,** Kale, B. K. and Muralidharan, K., AlphaScience International Ltd.,2015.
5. **Mathematical Statistics**, Mukhopadhyay, P., Books and Allied (p)Ltd.,2015.
6. **Modern Mathematical Statistics,** Dudewicz, E.J. and Mishra, S. N., John Wiley andSons,1988.
7. **Statistical Inference** , Casella & Berger, Duxbury advanced series, II nd edition,2002.

M. Sc. Part-I (Semester-I)
MST-413: Optimization Techniques-I (Credits: 04)

Course Objectives: Students will be able to,

1. Develop the optimization techniques that will be useful in the personal and professional life.
2. Learn the mathematical formulation of complex decision-making problems and arrives at optimal or near-optimal solutions using different techniques of operations research.

Credits (Total Credits 4)	**SEMESTER – I MST-413 Optimization Techniques**	**No.of hours per unit**
Unit - I		**(15)**
	a) Linear programming problem (LPP): Theorems related to the development of Simplex algorithm, theorems related to a basic feasible solution ; Reduction of a feasible solution to a basic feasible solution, Improvement of a basic feasible solution, Existence of unbounded solution, Optimality conditions and other related theorems (statements only), Examples based on these theorems. Revised simplex method. b) Artificial variable technique: Two phase method, redundancy.	
Unit - II		**(15)**
	a) Concept of Duality, related theorems, complementary slackness property and development of dual simplex algorithm. b) Sensitivity Analysis: Changes in the cost vector, requirement vector and non-basic activity vector; addition of new variables and addition of new constraints.	
Unit - III		**(15)**
	a) Theory of games: two-person zero sum games, minimax and maximin principles, Saddle point, mixed strategies; rules of dominance, solution of 2 x 2 game by algebraic method, Graphical method, Reduction of the game problem as LPP, Minimax and Maximin theorem. b) Dynamic Programming: The Recursion Equation Approach, Computational Procedure, Characteristics of Dynamic Programming, Solution of L.P.P. by Dynamic Programming	
Unit - IV		**(15)**
	a) Integer Linear Programming Problem (ILPP): The concept of cutting plane, cutting plane method for all ILPP and mixed ILLP, Branch and Bound method. b)Quadratic programming: Kuhn-Tucker conditions, methods due to Beale,Wolfe.	

Course Outcomes: Students are able to

1. Understand basics and formulation of linear programming problems and appreciate their limitations; solve linear programming problems using graphical method.
2. Apply simplex method to solve real life problems.
3. Solve artificial variable technique, duality theory, revised simplex method, sensitivity analysis.
4. Understand the concept of Game theory and dynamic programming to solve their problems and understand their real life applications.

BOOKS RECOMMENDED:

1. **Linear Programming**, Addison Wesley,1969.
2. **Operation Research An Introduction**, Taha H. A., Macmillan,1971.
3. **Operations Research**, KantiSwaroop& Gupta M. M., Sultan Chand & P. Gupta,1985.
4. **Operation Research**, D. S. Hira, Sultan Chand &Co.ltd,2010
5. **Operation Research Theory and Applications**, J. K. Sharma., Macmillan,2003.

M. Sc. Part-I (Semester-I)
MST-414: Sampling Theory (Credits: 02)

Course Objectives: Student will be able to,

1. Learn scientific view to conduct the survey in proper way to collect the data about specific perspective.
2. Learn variety of probability and nonprobability sampling methods for selecting a sample from a population

Credits (Total Credits 2)	**SEMESTER – I MST-414 Sampling Theory**	**No.of hours per unit**
Unit – I	**Unequal Varying Probability**	**(15)**
	Review of concept Sampling Method (SRS,Stratified, Systematic,Cluster) PPSWR methods: Cumulative total method, Lahiri's method related estimation Problems and PPSWOR methods and related estimation of a finite population mean (Horwitz-Thompson and Des Raj estimators for a general sample size and Murthy's estimator for a sample of size 2, Midzuno sampling, Rao-Hartley-Cochran sampling Strategy	
Unit – II	**Ratio and Regression Estimator**	**(15)**
	Use of supplementary information for estimation: ratio and regression estimators and their properties. Unbiased and almost unbiased ratio type estimators, Hansen–Hurwitz and Deming's model for the effect of call-backs. Random response techniques, dichotomous population, Warner's model, MLE in warner's model, unrelated question model, polychotomous population: use of binary and vector response, binary response and unrelated questions, Multi attribute situations	

Course Outcomes: Students are able to

1. Understand the basic concept of random sampling and different methods of sampling.
2. Apply unequal probability sampling designs viz. PPSWR, PPSWOR including Lahiri's method and

Murthy's estimator for survey.

3. Implement Cluster sampling, Two –stage sampling, Multistage sampling, Ratio and Regression estimation in real life problems.
4. Recognize non-sampling error, Response and non-response errors. Apply different model and technique to overcome errors.

BOOKS RECOMMENDED:

1. **Theory and methods of survey sampling** ,ParimalMukhopadhyay, Prentice Hall of India private limited, 2ndEdition,2008.
2. **Sampling Theory of surveys and applications**, Sukhatme P.V., SukhatmeS.& Ashok C, Iowa university press and Indian society of agricultural statistics, New Delhi,1984.
3. **Survey Sampling: Theory and Methods**, Chaudhuri and H. Stenger, chapman and hall/CRC, 2nd edition,2005.
4. **Sample Survey Theory**, Des Raj and Chandhok. P., Narosapublication,1998.
5. **Sampling Techniques** ,William G.Cochran, John and Wieley sons Inc, IIIrdedition 1977.
6. **Sampling Theory of Methods**, Murthy M.N., Statistical Publishing Society, Calcutta, 1977.
7. **Theory and Analysis of Sample Survey Designs**, SinghD.andChaudharyF.S., Wiley Eastern Limited,1986.
8. **Advance Sampling Theory and Applications (Volume I and II),** Singh, S., Kluwer Academic Publishers,2003.

M. Sc. Part-I (Semester-I)
MST-414: Population Studies (Credits: 02)

Course Objectives: Students will be able to,

1. Understand the need of population studies, vital statistics and concept of mortality and fertility.
2. Demonstrate understanding through data the concept of demography, Age- sex structure and migration

Credits (Total Credits 2)	SEMESTER – I MST-414 Population Studies	No. of hours per unit
Unit – I		**(15)**
	Introduction, Censuses, Vital Statistics, Sample Surveys, Sample Registration System, Service Statistics, **Population Age-Sex Structures**: Quality of Data and Adjustments Concept and Significance of Age in Demographic Analysis, Sex Composition, Errors in Demographic Data Whipple's Index, Myers' Blended Index, Digit Preference Quotients for Birth Intervals, UN Joint Score or Accuracy Index Based on Age Data in 5-year Age Groups, Smoothening of Age Distributions, Use of Polynomial and Other Curves, Adjustments for Very Young and Old Ages.	
Unit – II		**(15)**
	Davis and Blake Intermediate Determinants of Fertility, Bongaarts' Model of Proximate Determinants of Fertility, Coale's Indices, Cohort Rates, Parity progression ratio (PPR), Birth intervals, Lexis diagram. Life Tables, **Migration**: Importance of Migration and Concepts, Measures, Estimations of Migration Rates from Place of Birth Data, Estimation of Intercensal Migration	

	from Place of Birth Data from Two Censuses, Estimation of Survival Ratio, Estimation of Migration from Place of Last Residence Data, Limitations, Accuracy of Data, Estimation of Migration from Place of Residence at a Fixed Prior Date, Estimation of Net Migration from Vital Statistics Data.	

Books Recommended:

1) **Principles of Population Studies**, Asha A. Bhende and Tara Kanitkar, Sixteenth Revised Edition, Himalaya Publishing House, Mumbai(2003).
2) **The Methods and Materials of Demography**, Jacob S. Siegel and David a. Swanson, , Second Edition, Elsevier Science, USA(2004).
3) **Demographic Methods,** Hinde, Andrew London: Arnold (1998).
4) **Techniques of Demographic Analysis**,K.B. Pathak, and F. Ram, Mumbai: Himalaya Publishing House, (1998).
5) **Methods of Measuring Internal Migration United Nations,** Manual VI, UN, New York (1974)

M. Sc. Part-I (Semester-I)
MST-415 : Research Methodology (Credits: 04)

Course Objectives: Students will be able to,

1. Understand skills of basics of research.
2. Define research problems.
3. Gather data from experiments, Presented and analyzed.
4. Propose Hypothesis and learn the tool to test them.

Credits (Total Credits 4)	**SEMESTER – I RM Research Methodology**	**No. of hours per unit**
Unit – I		**(15)**
	Foundations of Research: Meaning, Objectives, Motivation, Utility. Concept of theory, empiricism, deductive and inductive theory. Characteristics of scientific method – Understanding the language of research – Concept, Construct, Definition, Variable. Research Process	
Unit – II		**(15)**
	Problem Identification & Formulation – Research Question – Investigation Question – Measurement Issues – Hypothesis – Qualities of a good Hypothesis –Null Hypothesis & Alternative Hypothesis. Hypothesis Testing – Logic & Importance Qualitative and Quantitative Research: Qualitative research – Quantitative research – Concept of measurement, causality, generalization, replication. Merging the two approaches	
Unit – III		**(15)**
	Data Analysis: Data Preparation – Univariate analysis (frequency tables, bar charts, pie charts, percentages), Bivariate analysis – Cross tabulations and Chi-square test including testing hypothesis of association.	
Unit - IV		**(15)**
	Interpretation of Data and Paper Writing – Layout of a Research Paper, Journals in Computer Science, Impact factor of Journals, When and where to publish ? Ethical issues related to publishing, Plagiarism and Self-Plagiarism.	

Course Outcomes: Students are able to

1. Perform basic of research work.
2. Understand and define research problems.

3. Collect, present and analyze data from experiments.
4. Purpose hypothesis and use the tools to test them.

Books Recommended: -

1. **Business Research Methods**, Donald Cooper & Pamela Schindler, TMGH, 9th edition, 2006.
2. **Business Research Methods,** Alan Bryman & Emma Bell, Oxford University Press, 2022.
3. **Research Methodology**, C. R. Kothari, New Age International Publishers, 2023.

M. Sc. Part-I (Semester-I)
MSP-416: Practical -I (Credits: 02)

Course Objectives: Students will be able to,

1) Understand application of Linear Algebra with illustration.
2) Compute UMVUE, MME and MLE using various methods of estimation.

Practical List

1. Linear Dependence and Independence of Vectors.
2. Solving systems of equations.
3. Inverse and g-inverse of a matrix.
4. Applications of Caley-Hamilton theorem.
5. Characteristics roots and vectors and their applications.
6. Construction of Unbiased estimator, Sufficient statistics
7. Methods of Estimation: MME and MLE.
8. Construction of UMVUE.
9. Methods of Scoring.
10. Bayesian inference.

Course Outcomes: Students are able to

1. Solve problem of matrix and understand application of Caley-Hamilton theorem.
2. Understand estimation methods.

BOOKS RECOMMENDED:

1. **An Introduction to Linear Statistical Models Vol 1**, Graybill, F.A., Mc Graw-HillBook Company Inc,1961.
2. **Matrix Algebra Useful for Statistics**, Searl S. B., Wiley,2006.
3. **Mathematical Statistics**, Mukhopadhyay, P., Books and Allied (p)Ltd.,2015.
4. **Introduction to Probability Theory and Mathematical Statistics**, Rohatgi, V. K. and Saleh,A.K. MD. E., John Wiley & sons, 3rd Edition. 2015.
5. **Operation Research Theory and Applications**, J. K. Sharma., Macmillan,2003

M. Sc. Part-I (Semester-I)
MSP-417: Practical-II (Credits: 02)

Course Objectives: Students will be able to,

1. Understand and implement theory in real life problems.
2. Perform mathematical/statistical computations, statistical data analysis using built-in functions in MSEXCEL and R and develop programs for various tasks.

Practical List:

1. Revised Simplex method and Dual Simplex Method.
2. Game Theory.
3. Quadratic programming
4. Integer programming
5. Dynamic Programming
6. Ratio, regression, Horvitz-Thompson method of estimations.
7. Stratified Sampling.
8. Systematic and cluster Sampling.
9. Multi-stage sampling
10. Non-sampling errors

Course Outcomes: Students are able to

1. Solve real life problems of optimization by using appropriate methods.
2. Perform/Solve various statistical problems though simulation, numerical and re-sampling techniques.

BOOKS RECOMMENDED:

1. **Operation Research Theory and Applications**, J. K. Sharma., Macmillan,2003
2. **Theory and methods of survey sampling** ,ParimalMukhopadhyay, Prentice Hall of India private limited, 2ndEdition,2008.
3. **Sample Survey Theory**, Des Raj and Chandhok. P., Narosapublication,1998.
4. **Sampling Techniques** ,William G.Cochran, John and Wieley sons Inc, IIIrd edition 1977

M. Sc. Part-I (Semester-II)
MST-421: Probability Theory (Credits: 04)

Course Objectives: Students should to understand

1. Concept of sets, field, probability measure and probability space.
2. Measurable function, random variable, related theorem and properties.
3. Concept of convergence and related theorem.
4. Concept of Weak and Strong laws of large numbers, related theorem and applications

Credits (Total Credits 4)	**SEMESTER – II MST-421 Probability Theory**	**No. of hours per unit**
Unit - I		**(15)**
	Classes of sets: Sequence of sets: limsup, liminf and limit of sequence of sets field, σ- field, σ-field generated by a class of sets, Borel σ- field. Probability measure, Probability space, properties of a probability measure, continuity, mixture of probability measures. Lebesgue and Lebesgue- Steltjes measures on R Independence of events	
Unit - II		**(15)**
	Measurable function, random variable, distribution function of a random variable, simple random variable, elementary random variable, liminf, limsup and limit of sequence of random variables. Method of obtaining a random variable as a limit of sequence of simple random variables. Integration of a measurable function with respect to a measure, expectation of a random variable, independence. Characteristic function, simple properties. Inversion theorem and uniqueness property (Statement only).	
Unit - III		**(15)**
	Monotone convergence theorem, Fatous Lemma, Dominated Convergence theorem, Borel- Cantelli Lemma, (Statements only), and their applications. Convergence of sequence of random variables, Convergence in distribution, Almost sure convergence, a characterizing property, convergence in probability, uniqueness of limit, Yule Slutsky results and preservation under continuous transform. Convergence in r^{th} mean, interrelationships (Statements only), their illustration with examples	
Unit - IV		**(15)**
	a) Weak and Strong laws of large numbers, Kolmogorov's three series theorem for almost sure convergence (Statement only), Liaponove's, Lindeberg- Feller Theorems on CLT (Statement only). Applications of the above results. b) Moment inequalities:- Markov, Chebychev, Holder, Minkowski and Jensen inequalities with their applications. Basic inequality Liapunov's.	

Course Outcomes: Students are able to

1. Learn the basic concepts of Sets, Sequence, Measurable function and limit.
2. Implementation of theoretical concept in example.
3. Recognize the measure theory, random variable, distribution function, limit of sequence variables.
4. Understand the concept of convergence and applications with example.

5. Understand the central limit theorem and large-sample approximations for common statistics.

BOOKS RECOMMENDED:

1. **Modern Probability Theory** , Bhat B. R., New age international (P) limited, IIIrd edition,1981.
2. **Probability Theory**, Alan Karr, Springer Verlag,1993.
3. **Probability &Measure**, Billingsley P., John Wiley and sons,1986.
4. **Probability Theory vol 1,** Athreya K. B. and Lahiri S., Trim series, (Hindustan BookAgency), 2006.
5. **Introduction to Probability and its Applications vol.II**, Feller, W. Wiley Eastern Ltd.,1969.
6. **Probability Theory**, Loeve, M., Springer Verlag,1978.

M. Sc. Part-I (Semester-II)
MST-422: Theory of Testing of Hypothesis (Credits: 04)

Course Objectives: Students should to

1. Understand the development of null and alternative hypotheses.
2. Know types of errors, most powerful test and concept of p- value.
3. Perform test of hypothesis as well as obtain MP, UMP tests.
4. Understand the concept of confidence interval, parametric and non-parametric tests.

Credits (Total Credits 4)	SEMESTER – II MST-422 Theory of Testing of Hypothesis	No. of hours per unit
Unit - I		**(15)**
	Problem of testing of Hypothesis, Simple and composite hypotheses. Randomized and non- randomized tests, Most powerful test, Neyman-Pearson Lemma and its applications. Determination of minimum sample size to achieve the desired strengths. Monotone likelihood ratio property, UMP test, power function of a test, existence of UMP. Tests for one-sided alternatives. Concept of p- value	
Unit - II		**(15)**
	UMP tests for two sided alternatives examples, their existence and non- existence. Generalized Neyman Pearson lemma, unbiased test, UMPU test and their existence in the case of exponential families (Statements of the theorems only).Similar tests, test with Neyman structure	
Unit - III		**(15)**
	Problem of confidence intervals, relation with testing of hypotheses problem, shortest length confidence intervals, UMA and UMAU confidence intervals.	
Unit - IV		**(15)**
	Likelihood ratio test and its application to standard distribution. Goodness of fit tests based on Chi-square distribution and application to contingency tables. Spearman's Rank Correlation Test; Kendall's Rank Correlation Test; Kruskal-Wallis Test; Fridman's Two-way analysis of variance by ranks.	

Course Outcomes: Students are able to

1. Formulate null and alternative hypotheses, compute probabilities of types of error, MP tests and MLR property.
2. Understand UMP and UMPU test with their applications.
3. Obtain asymptotic confidence interval of a parameter and its relation with testing of hypothesis problem.
4. Apply small, large sample size tests and non-parametric tests in real life problems.

BOOKS RECOMMENDED:

1. **Introduction to Probability Theory and Mathematical Statistics**, Rohatgi, V. K. and Saleh, A. K. MD. E., John Wiley & sons, 3rd Edition.2015.
2. **Parametric Inference: An Introduction,** Kale, B. K. and Muralidharan, K.,Alpha Science International Ltd.,2015.
3. **Modern Mathematical Statistics**, Dudewicz, E. J. and Mishra, S. N., John Wiley and Sons,1988.
4. **Theory of Point Estimation,** Lehmann, E. L., John Wiley & sons,1983.
5. **Mathematical Statistics: A decision theoretical approach**, Ferguson, T. S. , Academic press, 1967.
7. **Theory of Statistical Inference**, Zacks, S., JohnWileyandSons,NewYork,1971.
8. **Introduction to theory of nonparametric Statistics**, Randles, R. H. and Wolfe, D. A., Wiley,1979.
9. **Nonparametric Statistical Inference**, Gibbons J. D. and Chakraborti S., CRC Press, Fifth Edition,2010.

MST-423: Regression Analysis (Credits: 04)

Course Objectives: Students should to develop

1. The deeper understanding of the linear and non-linear regression model and its limitations.
2. The regression model and apply for specific perspective data in appropriate manner

Credits (Total Credits 4)	SEMESTER – II MST-423 Regression Analysis	No. of hours per unit
Unit - I		**(15)**
	Multiple regression model. Least square estimate and their Properties. Hypothesis testing, general linear hypothesis testing. Dummy variable. Residuals and their properties, Residual diagnostics. Transformation of variables: VST and Box-Cox Power transformation. Variable Selection Procedure: R –square, adjusted R-square, Mallows' Cp, forward, backward selection methods. AIC, BIC., Autocorrelation & Durbin – Watson test	
Unit - II		**(15)**
	Multicollinearity and Ridge regression. Robust Regression: Influential observation, leverage, outlier. Methods of detection of outlier and Influential observation. Estimation in presence of outlier: M estimator. Breakdown point, efficiency. Nonlinear regression models: Parameter estimation in a linear system. Transformation to a linear model. Statistical inference in nonlinear regression.	
Unit - III		**(15)**
	Polynomial models in one and two variables, orthogonal polynomials, smoothing splines: linear, quadratic, cubic, cubic-B.Non parametric regression: Kernel regression, locally weighted regression. Generalized linear models, Link function, ML and Quasi-likelihood estimation. Large sample tests about parameters, goodness of fit. Deviance analysis. Residual analysis : raw, Pearson, deviance, Anscombe, quantile. AIC, BIC.	
Unit - IV		**(15)**
	Logistic regression: logit, probit and cloglog model for single and multiple variables..ML estimation, Largesample test about parameter. Hosmer-Lemeshow test. ROC curve. Logistic regression for Nominal response .Proportional odds model. Poisson Regression : ML estimation using power link function. Testing significance of coefficients. Goodness of fit. Over dispersion, NB-2 model.	

Course Outcomes: Students are able to

1. Understand and apply multiple regression models in real life situations.
2. Understand concept of multicollinearity and non-linear regression.
3. Do residual analysis and will able to understand and apply the logistic regression.
4. Understand and apply the Poisson regression.

BOOKS RECOMMENDED:

1. **Introduction to Linear Regression Analysis**, Montgomery, D. C., Peck, E. A. and Vining G. G., Wiley, 2003.
2. **Applied Logistic Regression**, Hosmer, D. W. and Lemeshow, S.,Wiley,1989.
3. **Nonlinear Regression**, Seber, G. E. F. and Wild, C.J.,Wiley,1989.

4. **Generalized linear and mixed models**, McCulloch, C.E., & Searle, S.R.,Wiley series in probability and statistics, NewYork.,2003.
5. **Generalized Linear Models**, McCullagh, P. and Nelder, J. A.,Chapman&Hall.,1989.
6. **Negative binomial regression**, HilbeJ.,Cambridge University Press, 2nd Edition, 2011.

M. Sc. Part-I (Semester-II)
MST-424: Linear Model and Design of Experiment (Credits: 02)

Course Objectives: Students should to understand

1. The concept of linear model for experimental design
2. The connections between design choice and the resulting statistical analysis.
3. The statistical aspects of experimental design as a whole within the structure provided by general linear models

Credits (Total Credits 2)	SEMESTER – II MST-424 Linear Model and Design of Experiment	No.of hours per unit
Unit – I		**(15)**
	General linear model: definition, assumptions, concept of estimability, least squares estimation, BLUE, estimation space, error space, Gauss Markov theorem, variances and covariances of BLUEs, Distribution of quadratic forms for normal variables: related theorems (without proof), Tests of hypotheses in general linear models. Generalized linear mixed model: Structure of the model. Random effects. Marginal versus conditional models. Estimation by generalized equation and conditional likelihood.	
Unit – II		**(15)**
	Analysis of variance: one way classification, two way classification without interaction and with interaction with equal number of observations per cell, Estimation and tests of hypotheses, multiple comparison procedures: Three types of errors, Tukey, Sheffe and Bonferroni procedure. Two way classification with unequal number of observations per cell without interaction model, estimable parametric functions and their BLUEs, tests of hypotheses. Incomplete block design, concepts of connectedness, balancedness, and orthogonality, BIBD: Definition, properties and analysis, Symmetric BIBD.	

Course Outcomes: Students are able to

1. Understand General linear model, Guass Markov theorem, variances and covariance's of BLUEs.
2. Recognize one way classification, two way classifications without interaction and with interaction.
3. Apply this theory to the analysis of specific models in designing statistical experiments.

BOOKS RECOMMENDED:

1. **Course in Linear Models**, Kshirsagar A.M., Marcel Dekker,1983.

2. **Linear Estimation and Analysis of Experiments**, Joshi D. D., Wiley Estern Ltd, 1987.
3. **Design and analysis of experiments**, Das, M.N. and N.C. Giri, New Age International(P)Limited Publishers, 2nd edition,1986.
4. **Linear Models**, Searle S.R., John Wiley & Sons. New York,1971.
5. **Mathematics of Design of Experiments**, Chakravarti .M. C., Asia Publishing House, Bombay,1962.
6. **Incomplete block design**, Dey Aloke, Hindustan Book Agency,2010.
7. **Design and Analysis of Experiments**, Dean A. M. and Voss D. Springer,1999.

M. Sc. Part-I (Semester-II)
MST-424: Computational Statistics (Credits: 04)

Course Objectives: Students will be able to,

1. Understand the function of MS –EXCEL.
2. Understand the concept of Building web applications
3. Understand the concept of random number generators, simulation.
4. Understand the concept of Resampling techniques.

Credits (Total Credits 2)	**SEMESTER – II MST-424 Computational Statistics**	**No. of hours per unit**
Unit - I		**(15)**
	Concept of simulation. Concept of random number generators, true random number and pseudo-random number generators, requisites of a good random number generator. Congruential method of generating uniform random numbers. Algorithms for generating random numbers from well-known univariate discrete and continuous distributions, generating random vectors from multinomial, bivariate normal, and bivariate exponential distributions, and generating random numbers from a mixture of distributions (related results without proofs). Acceptance-Rejection Technique. Use of random numbers to evaluate integrals, to study the systems involving random variables, to estimate event probabilities and to find the expected value of random variables. Use of random numbers in statistical inference	
Unit - II		**(15)**
	Resampling techniques: Bootstrap methods, estimation of bias and standard errors, estimation of the sampling distribution, confidence intervals. Jackknife method: estimation of bias and standard errors, bias reduction method. The solution to system of linear equations: Jacobi and Gauss-Seidel methods with convergence analysis. Finding roots of the nonlinear equation: Newton-Raphson method, bisection method; Newton-Raphson for system of nonlinear equations. Numerical integration: quadrature formula, trapezoidal rule and Simpson's rule for single integral.	

Course Objectives: Students be able to,

1. Understand the function of MS –EXCEL.
2. Understand the concept of Building web applications
3. Understand the concept of random number generators, simulation.

BOOKS RECOMMENDED:

1. **An Introduction to Numerical Analysis**. Atkinson K. E., Wiley, 1989.
2. **Non- Uniform Random Variate Generation**, Devroye L., Springer- Verlag New York, 1986.
3. **An Introduction to the Bootstrap**, Efron B. and Tibshirani. R. J., Chapman and Hall, 1994.
4. **Elements of Simulation**, Morgan B. J. T., Chapman and Hall, 1984.
5. **Monte Carlo Statistical Methods**, Robert C. P. and Casella G., Springerverlag New York, Inc.1999.
6. **Simulation**, Ross. S. M., Academic Press Inc, 2006.
7. **Modern Simulation and Modeling**, Rubinstein, R. Y., Wiley Series in Probability and Statistics 1998.
8. **Statistical Computing**, William J., Kennedy, James E. Gentle, Marcel Dekker, 1980.

M. Sc. Part-I (Semester-II)
MST-426: Practical Paper-II (Credits: 02)

Course Objective: Students will be able to:

1. Fit multiple linear regression model to the data, perform diagnostic analysis and apply rectifying measures to overcome the problem of Multicollinearity, auto-correlation, outliers and non-linearity.
2. Fit Logistic and Poisson regression model to the data.
3. Test hypothesis about the parameters and develop appropriate MP, UMP and UMPU test in random experiments based on random sample

Practical List:

1. Multiple Linear Regression Model.
2. Multicollinearity.
3. Autocorrelation.
4. Nonlinear regression.
5. Logistic Regression.
6. Poisson Regression.
7. MP Test
8. UMP Test
9. UMPU Tests
10. Likelihood ratio tests.

Course Outcomes: Students are able to understand

1. Concepts of multivariate analysis techniques through example.
2. Testing of hypothesis process and different test.

BOOKS RECOMMENDED:

1. **Introduction to Linear Regression Analysis**, Montgomery, D. C., Peck, E. A. and Vining G. G., Wiley, 2003.
2. **Applied Logistic Regression**, Hosmer, D. W. and Lemeshow, S.,Wiley,1989.
3. **Nonlinear Regression**, Seber, G. E. F. and Wild, C.J.,Wiley,1989.
4. **Generalized linear and mixed models**, McCulloch, C.E., & Searle, S.R.,Wiley series in probability and statistics, NewYork.,2003

M. Sc. Part-I (Semester-II)
MST-427: Practical Paper-II (Credits: 02)

Course Objective: Students will be able to,

1. Test hypothesis about the parameters and provide interval estimates involved in random

experiments based on random sample.

2. Perform mathematical/statistical computations, statistical data analysis using built-in functions in MSEXCEL and R and develop programs for various tasks.

Practical List:

1. Confidence Intervals.
2. Non-parametric Tests-I
3. Non-parametric Tests-II
4. Linear Estimation: Estimation and Hypothesis testing.
5. ANOVA: One way orthogonal data without interaction.
6. ANOVA: Two way orthogonal data without interaction
7. ANOVA: Two way orthogonal data with interaction.
8. Two way non-orthogonal data without interaction
9. Analysis of BIBD.
10. General block design.

Course Outcomes: Students are able to understand

1. Concept of interval estimation and non-parametric testing process and different test.
2. One-way, two-way ANOVA and analysis of BIBD.

BOOKS RECOMMENDED:

1. **Parametric Inference: An Introduction,** Kale, B. K. and Muralidharan, K.,Alpha Science International Ltd.,2015.
2. **Introduction to Probability Theory and Mathematical Statistics**, Rohatgi, V. K. and Saleh, A. K. MD. E., John Wiley & sons, 3rd Edition.2015.
3. **An Introduction to Multivariate Statistical Analysis**, Anderson T. W., (John Wiely, 2ndEd.1984.
4. **Linear Estimation and Analysis of Experiments**, Joshi D. D., Wiley Estern Ltd, 1987.
5. **Theory and methods of survey sampling** ,Parimal Mukhopadhyay, Prentice Hall of India private limited, 2ndEdition,2008.