Revised Syllabi of M.Sc. in Statistics (Credit System)
(To be implemented in the Department of Statistics, Shivaji University)
(w.e. form 2013-2014)

1) **Title of the course:** M. Sc. (Statistics)
2) **Introduction:** M. Sc. Statistics program has semester pattern and credit system with four credits per paper. The program consists of 96 credits.
3) **Eligibility:** B. Sc. (Second class) with Statistics as principal

4) Structure of the course

The following table gives the scheme of Examination at M.Sc. Statistics according to the Revised Syllabus and pattern of Examination.

Notations : A six-character code is given to each paper. In MST "M" stands for M.Sc. and "ST" stands for Statistics. The first digit following MST is Semester Number. The second digit "0" stands for the compulsory theory paper, the digit "1" stands for a practical paper and the digit "2" stands for an elective paper / project work. The third digit indicated the serial number of paper in that semester.

Semester	**Paper No.**	**Title of the Paper**
I	MST-101	Statistical Mathematics I
	MST-102	Statistical Mathematics II
	MST-103	Distribution Theory
	MST-104	Estimation Theory
	MST-105	Statistical Computing
	MST-116	Practical I
II	MST-201	Probability Theory
	MST-202	Theory of Testing of Hypotheses
	MST-203	Multivariate Analysis
	MST-204	Linear Models & Design of Experiments
	MST-205	Sampling Theory
	MST-216	Practical II
III	MST-301	Asymptotic Inference
	MST-302	Elementary Stochastic Processes
	MST-303	Planning and Analysis of IndustrialExperiments.
	MST-316	Practical III

Elective Papers from which **Any Two** are to be chosen:
MST-321 Reliability Theory
MST-322 Regression Analysis
MST-323 Statistical Genetics
MST-324 Measure Theory
MST-325 Demography
MST-326 Medical Statistics
MST-327 Advanced Stochastic Processes

MST-328 Actuarial Statistics
MST-329 Dissertation

Semester	**Paper No.**	**Title of the Paper**
IV	MST-401	Optimization Techniques
	MST-416	Practical IV and Project

Elective Papers from which **Any Four** are to be chosen:

MST-421 Discrete Data Analysis
MST-422 Survival Analysis
MST-423 Industrial Statistics
MST-424 Time Series Analysis
MST-425 Statistical Ecology
MST-426 Econometrics
MST-427 Advanced Multivariate Analysis
MST-428 Data Warehousing and Data Mining
MST-429 Decision Theory

Note:-
a) Syllabus for some Elective courses has been given. Depending on need and demand, syllabus for other elective courses listed or of new elective courses will be submitted for approval.
b) There shall be CIE pattern in which internal examination will be for 20 marks, while University examination will be for 80 marks. Internal examination will be based on midterm test (10 marks), seminar (5 marks) and viva (5 marks).

Proposed nature of the Theory and Practical Question Paper at the M.Sc. Statistics course under the Semester Scheme:

1. Nature of the theory question papers:-
a) There shall be 7 questions each carrying 16 marks.
b) Question No.1 is compulsory and shall contain 10 short sub-questions each carrying2 marks. Students have to attempt any 8 sub-questions.
c) Students have to attempt any 4 questions from question No. 2 to 7.
d) Question No. 2 to 6 shall contain 2 to 4 sub-questions.
e) Question No. 7 will be short note type. Students are expected to solve any 4 out of 6,each carrying 4 marks.

2. Practical Paper :-

a) Semester I, II, III "Practical MST 116, MST 216, MST 316".

Internal (20) : There shall be 10 marks for day-to-day journal and internal test will be for 10 marks.

End of Term Examination (80): Practical Examination will be of 3 hrs. duration carrying 60 marks. There shall be 8 questions each of 12 marks, of which a student has to attempt any 5 questions.VIVA will be for 20 marks.

b) For Semester IV: MST-416

Internal (20) : There shall be 10 marks for day-to-day journal and internal test will be for 10 marks.

End of Term Examination (80) :

i) Practical Examination will be conducted for 30 marks and is 1.5 hours (90 Min.) duration. There shall be 5 questions eachcarrying 10 marks, of which a student has to attempt any 3 questions.

ii) Project work carries 30 marks. Project work consists of collecting data and analyzing the data and preparing report. 20 marks are reserved for VIVA.

iii) The Project work should be based on the field work. Field work report be submitted along with practical journal, which will be evaluated for 5 marks.

MST 101 : STATISTICAL MATHEMATICS – I

1. Set of real numbers, countable and uncountable sets, countability of rationals and uncountability of the interval (0,1) 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 these theorems.

(12 L + 3 T)

2. Sequence of real numbers, convergence, divergence. Cauchy sequence.Convergence of bounded monotone sequence. Limit inferior and limit superior of the sequences.Series of numbers, tests for convergence (without proof) test for absoluteconvergence, convergence of sequences of non-negative terms.

(12 L + 3 T)

3. 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.

Riemann, Riemann-Steltjes Integrals and their common properties. Integration by parts, Fundamental theorem on calculus, mean value theorem, their applications in finding functional of distributions. (12 L + 3 T)

4. Vector and Matrix differentiation, Maxima, minima of functions of several variables. Constrained maxima, minima, Lagrange's method, Taylor's theorem (without proof), implicit function theorem and their applications.

Multiple integrals, Change of variables, Improper integrals, Applications in multivariate distributions. Theorem on differentiation underintegral sign (without proof), Leibnitz rule (statement only) and applications.

(12 L + 3 T)

References:

1. Malik S. C. &Arora S.(1991) : Mathematical Analysis- Wiley Eastern Limited IInd edition.

2. Goldberg R. R. (1964) : Methods of Real Analysis- Blaisdell Publishing company, New york, U.S.A.
3. Bartle G. R. (1976): Element of Real Analysis- Wiley, 2nd edition.
4. Bartle G.R. &Sherbert D. R. (2000): Introduction to Real Analysis- John Wiley & Son Inc.
5. Royden (1988) : Principles of Real Analysis - Macmillian.
6. Widder (1989) : Advanced Calculus - Dover Publication.
7 .Apostol(1985) : Mathematical Analysis - Narosa Publishing House, T.M.

MST 102 : STATISTICAL MATHEMATICS – II

Unit I: Vector space, subspace, linear dependence and independence, basis, dimension of a vector space, example of vector spaces. Null space, Special types of matrices: elementary operations, rank of a matrix.Orthonormal basis, and orthogonal projection of a vector. Gram-Schmidtorthogonalisation, Kronekar product. Idempotent matrix, orthogonal matrix, inverse of a matrix, their simple properties,PartitionedMatrices. (12L+3T)

Unit II: Characteristic roots of a matrix, algebraic and geometric multiplicities, right and left characteristic vectors, characteristic vectors and their orthogonal property. Caley-Hamilton Theorem and its applications.Spectral decomposition, singular value decomposition and choleskey decomposition. (12L+3T)

Unit III: G-inverse, Moore – Penrose inverse, some basic properties of M. P. inverse. Solution of a system of homogenous and non-homogenous linear equations, theorem related to existence of solution and examples. (12L+3T)

Unit IV: Quadratic forms: definition, reduction and classification, simultaneous reduction of two quadraticforms, maxima and minima of ratio of quadratic forms. (12L+3T)

References:

1.Rao A. R. &Bhimashankaram P. (1992) : Linear Algebra. Tata Mc-Graw Hill, New Delhi.
2. Hadely G (1987): Linear Algebra - Narosa Publishing House.
3. Rao C. R. (1973) : Linear Statistical Inference and Its Applications , Second Edition Wiley Eastern.
4. Searl S. B.(1982) : Matrix Algebra Useful for Statistics – Wiley
5. Graybill , F.A (1961) : An introduction to linear Statistical models Vol-I McGraw-Hill Book company Inc.
6. Harville D. (1997) Matrix Algebra from Statistics perspective, Springer.
7. Schott J. Matrix Analysis for statistics, Wiley

MST 103 : DISTRIBUTION THEORY

1. Review of concept of random variable, c.d.f, characteristic properties of c.d.f., p.d.f., p.m.f., absolutely continuous and discrete distributions, mixtures of probability distributions, decomposition of mixture type c.d.f. into discrete and continuous c.d.f.'s. Brief review of basic distribution theory: Standard discrete and continuous distributions, truncated distributions (Truncated Binomial, Truncated Poisson, Truncated Normal etc.), three parameter Weibull, m.g.f., p.g.f., quantiles and symmetry of r.v., Hazard rate and cumulative hazard rate, IFR, DFR classes of distribution. (12L+3T)

2. Transformations, moments, m.g.f., p.g.f., Stieltjes moment problem, Sums of independent random variables, Convolutions, compound distributions. Random vectors, joint distributions, Independence, variance-covariance matrix, joint m.g.f., mixed moments, Conditional expectation and variances Bivariate Normal,Bivariate Exponential distributions. (12L+3T)

3. Order statistics: Probability Integral transformation, distribution of r-th order statistics, joint distribution of r^{th} and s^{th} order statistics ($r < s$) and their functions, distribution of spacings, normalized spacings with illustration to exponential case, distribution of sample range

Sampling distributions of statistics from univariate normal random samples, such as linear and quadratic forms, Fisher Cochran theorem, non-central χ^2, non central t and F distributions. (12L+3T)

References:

1. Rohatagi V.K.&Saleh A. K. Md. E.(2001) : Introduction to Probability Theory and Mathematical Statistics- John Wiley and sons Inc.
2. Johnson N. L. &Kotz. S. (1996) : Distributions in Statistics Vol-I,II and III, JohnWiley and Sons New york.
3. Johnson N.L. & S. Kotz. John : Multivariate Distributions - Wiley and sons New york.
4. Casella & Berger (2002) : Statistical Inference - Duxbury advanced series. IInd edition
5. C. R. Rao (1995) Linear Statistical Inference and Its Applications (Wiley Eastern) Second Edition
6. Dasgupta, A. (2010) Fundamentals of Probability: A First Course (Springer)

MST 104 : ESTIMATION THEORY

1. 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.

   (12L+3T)

2. 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. (12L+3T)

3. Method of maximum likelihood (MLE) and small sample properties of MLE, methodof scoring and application to estimation in multinomial distribution.MLE in non-regular families.Other methods of estimation: method of moments, minimum Chi square. (12L+3T)

4. The concept of prior distributions, various types of priors, noninformative , Jeffrey's, least favorable prior, posterior distribution; Posterior distribution conjugate family and standard examples of such families. Bayes and minimax rules; geometric interpretation for finite parameter space. (12L+3T)

References

1. Rohatgi V.K.(1976): Introduction to Probability Theory & Mathematical Statistics - John Wiley & sons.
2. Lehmann E. L. (1983) : Theory of Point Estimation - John Wiley & sons.
3. Rao C. R.(1973) : Linear Statistical Inference & its Applications, 2nd Ed wiley.
4. Kale B.K. (2005) : First Course on Parametric Inference, A **, 2nd** Edition**.** Narosa Publishing House.
5. George Casella, Roger L. Berger (2001) : Statistical Inference (second edition). Duxbury press.

MST 105: STATISTICAL COMPUTING

1. Concept of random number generator, congruential method of generating uniformvariate. Concept of simulation: Generation of Binomial, Poisson, Geometric, NegativeBinomial& Multinomial variate. Proofs of related results. Generation of continuous random variables covering Exponential, Normal, Gamma,Chi-square, Bivariate exponential, Bivariate Normal distributions, and mixture ofdistributions. (12L+3T)

2. Programming in C++: Concept of OOP, Data types, Variables, Statements, Expressions, Control structures, Looping, Functions, Pointers. Programming for problems based on Unit 1. (12L+3T)
3. Excel: Introduction to MSEXCEL and exercises on using EXCEL for Statistical analysis covering frequency distribution, histograms, t-test, test for Independence in2x2 contingency tables.

R – Language. : Introduction to R, elementary programming, application to data analysis:Descriptive statistics, Fitting of Distributions, Cross Tables, Correlations andRegression, Hypothesis Testing, ANOVA. (12L+3T)

4. Bias reduction methods, Jack-Knife estimator-its properties and limitations. Boot –Strap method and its simple properties.

Numerical Methods: Newton Raphson method, Regula falsi method, Numerical integration using Trapezoidal rule and Simpson's rule for single and double integrals.

(12L+3T)

References

1. Morgan B. J. T.(1984) : Elements of Simulation. Chapman and Hall.
2. Kennedy William J.,Jr. jamesE.Gentle. (1980) : Statistical Computing *Marcel Dekker , Inc. New york and Basel*.
3. Christion P. Robert, George casella (1999) : Monte carlo Statistical Methods, Springer-verlag, New York, Inc.
4. Luc Devroye (1986) : Non- Uniform Random Variate Generation; Springer-Verlag New York Berlin-Heidelberg Tokyo.
5. Rubinstein, R. Y. (1998)Modern Simulation and Modeling (Wiley Series in Probability and Statistics)

MST 116: PRACTICAL –I

1. Linear dependence of Vector and rank a matrix.
2. Gram-Schmidt orthogonalisation method.
3. Solving systems of equations.
4. Determinant, Inverse and g-inverse of a matrix.
5. Applications of Caley-Hamilton theorem.
6. Inverse of a Partitioned matrix.
7. Characteristics roots and vectors and their applications.
8. Classifications and reduction of quadratic forms.
9. Sketching of d.fs.
10. Model sampling from univariate and bivariate.
11. Construction of UMVUE.
12. Methods of Estimation : MML and MLE.
13. Methods of Scoring.
14. Practicals on Baysian inference.
15. –20. Programming assignments on MST –105 Course.(Software to be used : R/MINITAB/MATLAB/SAS/SYSTAT depends on availability)

MST 201: PROBABILITY THEORY

1. Classes of sets: Sequence of sets: limsup, liminf and limit of sequence of sets field,σ-field, σ-field generated by a class, Borelσ-field.
   Probability measure, Probability space, properties of probability measure – continuity, mixture of probability measures. Lebesgue and Lebesgue - Steltjes measures on R. Independence of events. (12L+3T)
2. Measurable function, random variable, distribution function of a random variable,simple random variable, elementary random variable liminf, limsup and limit ofsequence of random variables. Method of obtaining a random variable as a limit ofsequence 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).
   (12L+3T)
3. Monotone convergence theorem, Fatous Lemma, Dominated Convergence theorem, Borel - Cantelli Lemma, and their applications. Convergence of sequence of random variables, Convergence in distribution, continuity theorem

(Statement only), Almost sure convergence, acharacterizing property , convergence in probability, uniqueness of limit, Yule Slutsky results and preservation under continuoustransform.(Statements only), convergence in r^{th} mean, interrelationships. (12L+3T)

4. Weak and Strong laws of large numbers, Kolmogorov's three series theorem for almost sureconvergence(Statement only), Liaponove's, Lindeberg-Feller Theorems on CLT(Statement only).Applications of the above results. (12L+3T)

References:

1. Bhat B. R.(1981) : Modern Probability Theory –IIIrd edition :New age international (P)limited,
2. Alan Karr,(1993) : Probability Theory – Springer Verlag.
3. Billingsley P.(1986) : Probability & Measure –John Wiley and sons
4. AthreyaK. B. and Lahiri S. (2006). Probability Theory vol 41, Trim series, (Hindustan Book Agency).
5. Feller, W. (1969). Introduction to Probability and its Applications vol.II (Wiley Eastern Ltd.)
6. Loeve, M. (1978). Probability Theory (Springer Verlag). Fourth edition.

MST 202 : THEORY OF TESTING OF HYPOTHESES

UnitI: 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. (12L+3T)

Unit II: Monotone likelihood ratio property, power function of a test, existence of UMP. Tests for one-sided alternatives, UMP tests for two sidedalternatives examples, their existence and non-existence. (12L+3T)

UnitIII: 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.Problem of confidence intervals,relation with testing of hypotheses problem, UMA and UMAU confidence intervals, shortest length confidence intervals. (12L+3T)

Unit IV : Likelihood ratio test and its application to standard distribution, goodness of fit tests based on Chi-square distribution and application to contingency tables.Non-parametric tests, One and two sample problem; Sign test, Run test, Wilcoxon Signed-Rank test, Man-Whiteny test. U-Statistics; U-Statistics theorem for one sample and two samples (statements only). (12L+3T)

References:

1. Kale B.K. (1999) : A First Course on parametric Inference. Narosa , IInd Edition
2. Rohatgi V.K. (1988): Introduction to Probability and Mathematical Statistics.Wiley Eastem Ltd. New Delhi. Student Edition.
3. Dudewicz E.J. & Mishra S. N. (1988) : Modern Mathematical Statistics. Wiley Seris in Prob., Stat. John.Wiley & Sons. New York. International studentsedition.
4. Lehman E. L. (1987) : Theory of testing of hypotheses. Students Edition.
5. Ferguson T.S. (1967) : mathematical Statistics. A decision theoretical approach.Academic press.

6. Zacks S. (1971) : Theory of Statistical Inference John Wiley and Sons. NewYork.
7. Randles and Wolfe Introduction to nonparametric Statistics

MST 203 : MULTIVARIATE ANALYSIS

Unit-1Exploratory multivariate data analysis, sample mean vector, sample dispersion matrix, correlation matrix, graphical representation, means, variances, covariance's, correlations of linear transforms.Introduction to principle component analysis, dimension reduction, canonical correlation coefficients and canonical variables. (12L+3T)

Unit-2: Multivariate normal distribution, two definitions and their equivalence , singular and nonsingular normal distribution, characteristic function, moments, marginal and conditional distributions. Maximum likelihood estimators of the parameters of the multivariate normal distribution and their sampling distributions. (12L+3T)

Unit-3: Hotelling's T2 Statistic and its null distribution. Applications of T2 statistics and its relationship with Mahalanobis' D^2 statistic. Confidence region for the mean vector Wishart matrix and its distribution, properties of Wishart distribution, distribution of generalized variance. (12L+3T)

Unit-4: Discrimination and classification. Fisher's discriminant function and likelihood ratio procedure, minimum ECM rule, Rao's U statistics and its use in tests associated with discriminant function, classification with three populations. Introduction to factor analysis, Cluster analysis, Heirarchical and non-Heirarchical clustering. Single, Complete, average linkage method and k-means clustering. (12L+3T)

Reference:-

1. Kshirsagar A. M.(1972) : Multivariate Analysis. Maral-Dekker.
2. Johnson, R.A. and Wichern . D.W (2002) : Applied multivariate Analysis. 5th Ad.Prentice –Hall.
3. Anderson T. W. (1984) : An introduction to Multivariate statistical Analysis 2nd Ed. John Wiely.
4. Morrison D.F. (1976) : Multivariate Statistical Methods McGraw-Hill.

MST 204 : LINEAR MODELS AND DESIGN OF EXPERIMENTS

1. General linear model: definition, assumptions, concept of estimability, least squares estimation, BLUE, error space, estimation space, Guass Markov theorem, variances and covariances of BLUEs.

Distribution of quadratic forms for normal variables: related theorems (without proof). Tests of hypothesis in general linear models. (12L+3T)

2. Analysis of variance : one way classification, two way classification without interaction and with interaction with equal number of observations per cell. Estimation and related tests of hypothesis,Multiple comparisons: Three types of errors, Tukey ,Sheffe and Bonferroni procedure. (12L+3T)

3.General block design : Two way classification with unequal number of observations per cell (without interaction), connectedness, balancedness , orthogonality, related tests of hypothesis.

BIBD : Definition, parametric relationship, Inter and Intra Block analysis, Symmetric BIBD. (12L+3T)

4. Analysis of Covariance: estimation of parameters, related tests of hypothesis. General theory and application of one way and two way set up.Introduction to mixed and random effects models. (12L+3T)

References:

1. Kshirsagar A. M.(1983) : Course in Linear Models - Marcel dekker.
2. Joshi D. D.(1987) : Linear Estimation and Analysis of Experiments - Wiley Estern Ltd.
3. Giri N. S. & Das M. N.(1979) : Design and Analysis of Experiments - Wiley Estern Ltd.
4. Searle S. R. (1971): Linear Models - John Wiley & Sons. New York.
5. Chakravarti . M. C.(1962) : Mathematics of Design of Experiments - Asia Publishing House , Bombay.

MST 205: SAMPLING THEORY

Unit I:Review of concept of population and sample, Need for Sampling, census and sample surveys, basic concepts in sampling and designing of large-scale surveys design, sampling scheme and sampling strategy,simple random sampling with and without replacement (SRSWR, SRSWOR).

Stratified sampling: Stratification, allocation and estimation problems,construction of Strata, deepstratification, method of collapsed strata. Systematic sampling: The sample mean and its variance, comparison of systematic with random sampling, comparison of systematic sampling with stratified sampling, comparison of systematic with simple and stratified random sampling for certain specified population. (12L+3T)

Unit II: PPSWR methods: Cumulative total method, Lahiri's method related estimationProblems 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, Poisson and Modified Poisson sampling strategy. (12L+3T)

Unit III: Use of supplementary information for estimation: ratio and regression estimators and their properties. Unbiased and almost unbiased ratio type estimators, Doublesampling. Cluster sampling. Two – stage sampling with equal number of second stage units. (12L+3T)

Unit IV: Non - sampling errors: Response and non- response errors. Hansen – Horwitz and Demings model for the effect of call-backs. Random response techniques, dichotomous population, Warners model, MLE in Warners model, Unrelated question model, polychotomouspopulation :use of binary and vector response, binary response and unrelated questions, Multiattribute situations. (12L+3T)

References

1. Sukhatme P. V., Sukhatme S. & Ashok C : Sampling Theory of surveys and applications – Piyush publications
2. Des Raj and Chandhok. P. (1998) : Sample Survey Theory - Narosa publication.
3. William G. Cochran. (1977) : Sampling Techniques- IIIrd edition –John and Wieleysons Inc.
4. ParimalMukhopadhyay (1998) : Theory and methods of survey sampling – Prentice Hall of India private limited.
5. Murthy M.N. (1977) : Sampling Theory of Methods - Statistical Publishing Society, Calcutta.

MST 216- PRACTICAL –II

1. Sampling from multivariate distribution and Graphical techniques.
2..Data reduction techniques: Principle component analysis, Canonical correlations and Factor Analysis.
   Multiple and partial correlation.
3. Application of Hotelling's T2 statistics.
4. Discriminant Analysis
5. Cluster Analysis
6. M.P. UMP, and UMPU Tests
7. Likelihood ratio tests.
8. Confidence Intervals.
9. Non-parametric Tests.
10. Linear Estimation: Estimation and Hypothesis testing.
11. ANOVA : One way and two way orthogonal data without interaction.
12. ANOVA: Two way orthogonal data with interaction
13. Two way non-orthogonal data without interaction
14. Analysis of BIBD.
15. Analysis of general block design.
16. Basic sampling designs.
17. Ratio, regression, Horvitz-Thompson method of estimations.
18. Stratified, Systematic and cluster Sampling.
19. Multi-stage sampling
20. Non-sampling errors.