

As Per NEP 2020

University of Mumbai



Title of the program

- | | | |
|----------------------------------|---|----------------|
| A- P.G. Diploma in Statistics | } | 2023-24 |
| B- M.Sc. (Statistics) (Two Year) | | |
| C- M.Sc. (Statistics) (One Year) | | |
- **2027-28**

Syllabus for

Semester – Sem I & II

Ref: GR dated 16th May, 2023 for Credit Structure of PG

Preamble

1) Introduction

M.Sc. Statistics is a two years (four semesters) program. The program consists of 88 credits, for each semester there are 22 credits. In semester I, “Research Methodology” is a mandatory course. In semester I, II and semester III, there are three mandatory courses each of four credits and one course can be selected from the available list of elective courses whereas in semester IV there are two mandatory courses each of four credits and one course can be selected from the available list of elective courses. An elective course consists of a theory course of two credits and practical course of two credits. In addition there is one practical course of two credits in each semester.

2) Aims and Objectives

The program accentuates both the core and modern applications of statistics. The program is structured so that students will have in depth knowledge of Statistics for pursuing their higher studies and also necessary skills in statistics for the employability in corporate. The program has the unique features like, field projects, internships, research project, and adequate amount of courses in core as well as in applied Statistics.

3) Learning Outcomes

On completion of this program learners will have,

- a) Knowledge of ethical values to become a responsible researcher in Statistics.
- b) Fair knowledge of core statistics such as probability theory, distribution theory, statistical modeling, multivariate techniques etc.
- c) Fluency in statistical computing using R- language, Python etc.
- d) Knowledge of reframing real situation information into statistical language, analyzing the data and to draw valid inferences based on it.

4) Any other point (if any)

5) Baskets of Electives

For semester I:

- Sampling Techniques and Statistics Practical – II,
- Optimization Techniques and Statistics Practical – II,
- Basic Statistics for Data Analysis and Statistics Practical – II (for non-Statistics students)

For semester II:

- Nonparametric Inference and Statistics Practical – IV,
- Operations Management and Statistics Practical – IV,
- Statistical Process control –I and Statistics Practical – IV,
- Elementary Statistics for Data Analysis and Statistics Practical – IV (for non-Statistics students)

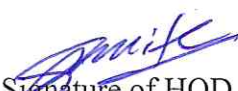
6) Credit Structure of the Program (Table as per (Parishishth 1) with sign of HOD and Dean):

M.Sc. (Statistics) Part I (Semester I and Semester II)

Year (2 Yr PG)	Level	Sem. (2 Yr)	Major		RM	OJT / FP	RP	Cu m. Cr.	Degree
			Mandatory*	Electives Any one					
I	6.0	Sem I	502: Probability Theory (04) 503: Linear Models (04) 504: Statistical Inference I (04) 505: Statistics Practical I (02)	E1 506 (A): Sampling Techniques (02) E1 506 (B): Statistics Practical II (02) 					

M.Sc. (Statistics) Part I (Semester I and Semester II)

II	6.5	Sem III	601: Multivariate Analysis II (04) 602: Design of Experiments- I (04) 603: Stochastic Processes (04) 604: Statistics Practical V (02)	E1 605 (A): Elements of Data Science – I (02) E1 605 (B): Statistics Practical VI (02) OR E2 605 (A): Statistical Process Control - II (02) E2 605 (B): Statistics Practical VI (02) OR E3 605 (A): Financial Mathematics – I (02) E3 605 (B): Statistics Practical VI (02) OR E4 605 (A): Statistics in Insurance – I (02) E4 605 (B): Statistics Practical VI (02)			04	22	PG Degree After 3-Yr UG	
		Sem IV	607: Time series Analysis (04) 608: Reliability and Survival Analysis (04) 609: Design of Experiments- II (02) 610: Statistics Practical VII (02)	E1 611 (A): Elements of Data Science – II (02) E1 611 (B): Statistics Practical VIII (02) OR E2 611 (A): Financial Mathematics – II (02) E2 611 (B): Statistics Practical VIII (02) OR E3 611 (A): Statistics in Insurance- II (02) E3 611 (B): Statistics Practical VIII (02) OR E4 611 (A): Statistical Decision Theory (02) E4 611 (B): Statistics Practical VIII (02)			6	22		
		Cum. Cr. for 1 Yr PG Degree		26	8			10		44
		Cum. Cr. for 2 Yr PG Degree		54	16	4	4	10		88


Signature of HOD

Prof. S. P. Gite

Head of the Statistics Department


Signature of Dean,
Prof. Shivram S. Garje
Science Faculty

DR. S. P. GITE
Head Department of Statistics
University of Mumbai
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Syllabus
M.Sc. (Statistics) Part - I
(Semester I and Semester II)
Academic year 2023-2024

STRUCTURE OF THE SYLLABUS

M.Sc. Statistics is a two years (four semesters) program. The program consists of 88 credits, for each semester there are 22 credits. In semester one “Research methods in Statistics” is a compulsory course. In semester I, II and semester III, there are three mandatory courses each of four credits and one course can be selected from the available list of elective courses whereas in semester IV there are two mandatory courses each of four credits and one course can be selected from the available list of elective courses. An elective course consists of a theory course of two credits and practical course of two credits. In addition there is one practical course of two credits in each semester.

Following is the table showing the proposed courses (mandatory and elective) to be covered in semester I and semester II of first year M.Sc. program.

SEMESTER I**MANDATORY COURSES**

Mandatory courses				Elective courses	RM	OJ T/ FP
Course code	Course Title	Credits	Total number of lectures			
502	Probability Theory	04	60	Learner can select one theory course as an elective course from the following list of subjects and practical course based on the selected theory course.	501: Research Methodology in Statistics (04 credits)	---
503	Linear models	04	60			
504	Statistical Inference - I	04	60			
505	Statistics Practical – I	02	60			

LIST OF ELECTIVES

Elective courses			
Course code	Course Title	Credits	Total number of lectures
E1 506 (A)	Sampling Techniques and	02	30
E1 506 (B)	Statistics Practical - II	02	60
E2 506 (A)	Optimization Techniques and	02	30
E2 506 (B)	Statistics Practical - II	02	60
E3 506 (A)	Basic Statistics for Data Analysis and	02	30
E3 506 (B)	Statistics Practical - II	02	60

SEMESTER II**MANDATORY COURSES**

Mandatory courses				Elective courses	RM	OJ T/ FP
Course code	Course Title	Credits	Total number of lectures			
507	Multivariate Analysis – I	04	60	Learner can select one theory course as an elective course from the following list of subjects and practical course based on the selected theory course.	---	OJT /FP
508	General Linear models	04	60			
509	Statistical Inference – II	04	60			
510	Statistics Practical – III	02	60			

LIST OF ELECTIVES

Elective courses			
Course code	Course Title	Credits	Total number of lectures
E1 511 (A)	Nonparametric Inference and	02	30
E1 511 (B)	Statistics Practical – II	02	60
E2 511 (A)	Operations Management and	02	30
E2 511 (B)	Statistics Practical – II	02	60
E3 511 (A)	Elementary statistics for Data Analysis	02	30
E3 511 (B)	and Statistics Practical – II	02	60
E3 511 (A)	Statistical Process Control- I and	02	30
E3 511 (B)	Statistics Practical-II	02	60

DURATION OF THEORY COURSE

Duration of each of the theory course will be 60 hours for entire semester. Each theory course will be of four credits having four hours of classroom teaching per week. Syllabus of each theory course is divided into two modules each should be covered in 30 lectures each of one hour.

DURATION OF PRACTICAL COURSE

Duration of each of the practical course will be 60 hours for entire semester. Each practical course will be of two credits. Each practical will have four hours of practical session per week per batch of practical. Each batch of practical consists of 10 students.

PROGRAM LEARNING OUTCOMES

The program accentuates both the core and modern applications of statistics. The program is structured so that students will have in depth knowledge of Statistics for pursuing their higher studies and also necessary skills in statistics for the employability in corporate. The program has the unique features like, field projects, internships, research project, and adequate amount of courses in core as well as in applied Statistics.

On completion of this program learners will have,

- PO 1) Knowledge of ethical values to become a responsible researcher in Statistics.
- PO 2) Fair knowledge of core statistics such as probability theory, distribution theory, statistical modeling, multivariate techniques
- PO 3) Fluency in statistical computing using R- language, Python.
- PO 4) Knowledge of reframing real situation information into statistical language, analyzing the data and to draw valid inferences based on it.

DETAILED SYLLABUS**Semester I****Mandatory courses****501: Research Methodology in Statistics**

Programme Name:	M.Sc. Statistics	Course Code and Name:	501:Research Methodology in Statistics
Total Credits:	04	Total Marks:	100
University assessment:	50	College assessment:	50
Pre requisite: Probability sampling: simple random sampling, stratified random sampling; elementary concepts: probability, random variable, probability mass function, probability density function.			
Course outcomes: After completion of the course learners will, CO 1) Understand meaning of research. CO 2) Able to define research problem. CO 3) Know methods of collecting data statistically. CO 4) Know how to handle missing observations statistically in data. CO 5) Able to use open access journals and databases. CO 6) Know research ethics and ethical practices for future research.			
MODULE I:			(2 CREDITS)
Unit 1:	a) Meaning of research, objectives of research, types of research, research process, research design, measurement and scaling, scaling techniques,		

	types of data, Statistics in scientific Research: research design, types of statistical research: empirical, field experiments, laboratory experiments. b) Data collection methods: population, sample, sampling frame, sampling unit, determination of sample size, review of simple random sampling. c) Review of stratified random sampling, different allocations, post stratifications, collapsed strata, non-response and methods for recovering non-response.
Unit 2:	a) Data analysis: data editing, coding, imputation of missing values, report writing. b) Publication Ethics: Philosophy and ethics, scientific misconducts, plagiarism, duplicate and overlapping publications, best practices, conflicts of interest, violation of publication ethics, authorship and contributorship. c) Open access publications, research databases: Web of Science, Scopus etc. different research Metrics: impact factor, h-index, g index, i10 index, cite score etc.
MODULE II: (2 CREDITS)	
Unit 3:	a) Random variable, Distribution function, discrete, continuous, mixed type distributions, Properties of distribution function, Jordan decomposition theorem, probability integral transform. b) Expectation and moments, non existence of moments, moment inequalities: Jensen's inequality, Markov inequality, C_r inequality, basic inequality, Holder's inequality, Minkowski's inequality, Lyapunov inequality, their applications, examples. c) Multiple random variables, joint cumulative distribution function, joint probability function.
Unit 4:	a) Joint moments, correlation, review of moment generating function and probability generating function, characteristic function, joint moment generating function. b) Conditional probability distribution, conditional expectation. c) Univariate and multivariate transformations.
References:	

- Beall, J. (2012): Predatory publishers and corrupting open access. Nature. 489,(7415), 179
- Bird, A. (2006) Philosophy of Science. Routledge.
- Buren, Stef van (2012): Flexible imputation of missing data. Chapman and Hall
- Bhat B.R. (1999): Modern Probability Theory: An Introductory test book. 3rd edition. New Age International.
- Hogg, R. V. and Craig, A. T. (1995): Introduction to Mathematical Statistics. Pearson.
- Goon, A. M., Gupta, M. K. and Dasgupta, B. (1998): An outline of statistical theory. Volume I. The world press.
- Kothari, C. R. (2014): Research Methodology. Third edition, Wiley Eastern limited.
- Mood, A. M., Graybill, F. A. and Boes, D. C. (2005): Introduction to the theory of Statistics. Tata McGraw-Hill. Third edition.
- Rao, C. R. (2002): Linear statistical Inference and its Applications. Wiley.
- Rohatgi V.K. & Saleh A.K. Md. Ehasanes (2001) : An Introduction to Probability and Statistics. Wiley.
- Ross, S. M. (2014): Introduction to Probability Models. 11th edition. Elsevier.
- Patten, M. L. and Newhart, M. (2017): Understanding research methods: An overview of essentials. 10th edition. Routledge.
- Chaddah, P. (2018): Ethics in competitive research: Do not get scooped: do not get plagiarize.
- Muralidhar, K. Ghosh, A. and Singhvi, A. K. (2019): Ethics in science education. Research and Governance, Indian national science academy, New Delhi

502: Probability Theory

Programme Name:	M.Sc. Statistics	Course Code and Name:	502: Probability Theory
Total Credits:	04	Total Marks:	100
University assessment:	50	College assessment:	50
Pre requisite: Real system, types of intervals, absolute values and its properties, functions, sets and operations, bounded and unbounded set, supremum, infimum, countable, uncountable sets, neighbourhood of a point, limit point of a set.			
Course outcomes: After completion of the course learners will have, CO 1) Foundation knowledge in sequence, series and function.			

CO 2) Foundation knowledge in differential and integral calculus.	
CO 3) Knowledge of concepts like, random experiment, probability, conditional probability.	
CO 4) Knowledge to applying probability models.	
CO 5) Knowledge to find behavior of sequence of random variables for large n.	
MODULE I: (2 CREDITS)	
Unit 1:	a) Real sequence: limit points of sequence, limit inferior, limit superior of a sequence, convergence of a sequence, divergence of a sequence, Cauchy's principle, monotone sequence, some important sequences. b) Infinite series: necessary condition, Cauchy's principle, positive term series and their tests of convergence, alternating series, absolute and conditional convergence, Leibnitz theorem, Cauchy product of two series and its convergence, power series, radius of convergence. c) Function: limit of a function, left and right hand limit, continuity, uniform continuity.
Unit 2:	a) Review of derivative, functions of several variables, limit point, repeated limits, partial derivatives of higher order, change of variables, Taylor series expansion, intermediate forms, applications of derivative, implicit and explicit functions. b) Introduction to Riemann integration, Riemann-Stieltjes integration, improper integration, Lebesgue integration, limit of integration, convergence, Integration by parts, integration under differentiation, Change of limits of integration. c) Sequence and series of functions, uniform convergence, pointwise convergence.
MODULE II: (2 CREDITS)	
Unit 3:	a) Sets, classes of sets, algebra of sets, limits of sequence of sets. Field, sigma field, Borel sigma field, minimal sigma field, examples. b) Random experiment, sample space, event, probability, probability as a measure, probability space, Bonferroni's inequality, Booles' inequality, examples. c) Conditional probability, independence, examples.
Unit 4:	a) Random variable, convergence of sequence of random variables, convergence in distribution, convergence in probability, convergence almost surely, convergence in r^{th} mean, their interrelations,

	b) Law of large numbers: weak, strong, Central limit theorem: Lindberg Levy's central limit theorem. c) Monotone convergence theorem, dominated convergence theorem, continuity theorem on probability, Borel zero-one law, Borel-Cantelli lemma.
References: • Apostol, T. M. (1974): Mathematical Analysis. 2nd edition, Narosa Publishing house. • Bartle G. and Sherbert, D. R. (2000): Introduction to Real Analysis. 3rd edition. Wiley. • Bhat B.R. (1999): Modern Probability Theory: An Introductory text book. 3rd edition. New Age International. • Chandra, T. and Gangopadhyay, S. (2017): Fundamentals of Probability Theory. Narosa Publishing House. • Gut, A. (2005): Probability: A Graduate Course. Springer. • Kumar, A and Kumaresan S. (2015): A Basic course in Real analysis. CRC Press. • Malik, S. C. and Arora, S. (2017): Mathematical Analysis. 5th edition. New age International Publishers. • Rohatgi V.K. and Saleh A.K. Md. Ehasanes (2001): An Introduction to Probability and Statistics. Wiley. • Rudin, W. (1976): Principles of Mathematical Analysis. 3rd edition. McGraw-Hill.	

503: Linear models

Programme Name:	M.Sc. Statistics	Course Code and Name:	503: Linear Models
Total Credits:	04	Total Marks:	100
University assessment:	50	College assessment:	50
Pre requisite: Basic operations of matrices, determinant, types of matrices, inverse of a matrix			
Course outcomes: After completion of the course learners will, CO 1) Understand elementary matrix theory. CO 2) Understand the basic theory of Analysis of Variance. CO 3) Understand the basic theory of Analysis of covariance CO 4) Able to analyze real life data using different analysis of variance models.			
MODULE I:			(2 CREDITS)
Unit 1:	a) Vector Spaces, Linear dependence and independence of vectors.		

	Determinant of Matrices: Definition, Properties and applications of determinants for higher order. b) Idempotent matrix, orthogonal matrix, symmetric matrix, Inverse of matrix, trace of matrix, Partition of matrix, Rank of matrix, echelon forms, canonical form. Generalized inverse, Solving linear homogeneous and nonhomogeneous equations. c) Characteristic roots and characteristic vectors, properties of characteristics roots. Quadratic forms, positive and Positive semi definite matrix
Unit 2:	a) Gauss-Markoff set up, Linear parametric function and its estimability, Gauss-Markoff theorem, normal equations, least square estimators, BLUE. b) Fundamental theorems of least square theory, conditional error sums of squares, interval estimates and test of hypothesis, generalized least square estimators.
MODULE II: (2 CREDITS)	
Unit 3:	a) One –way analysis of variance model, estimation and testing of estimable parameters, checking assumptions of the model. Bartlett’s test and Levene’s test, simultaneous confidence intervals: Scheffe’s, Bonferroni and Tukey’s interval. b) Two – way analysis of variance model with and without interaction effect, one observation per cell and r observations per cell. Tukey’s test for non additivity. Two – way classification model with and without interaction effect with unequal number of observations per cell.
Unit 4:	a) Analysis of variance with random and fixed effect models: estimation and testing of variance components in one-way, two-way and multiway analysis of variance models. b) Analysis of Covariance: Model, BLUE, ANCOVA table, testing of hypotheses, use of ANCOVA for missing observation.
References: • Bapat, R. B. (2012): Linear Algebra and Linear models. Hindustan Book Agency. Third edition • Graybill, F. A (1976): Theory and applications of the linear model. Duxbury Press. • Hohn, F. E. (1973): Elements of Matrix Algebra, Macmillan.	

- Kshirsagar, A. M. (1983): A course in Linear Models. Marcel Dekker.
- Rao, C. R. (2002): Linear Statistical Inference and its Applications, Wiley Eastern
- Rao, A. R. and Bhimasankaram, P. (1992): Linear Algebra. Tata McGraw-Hill, new Delhi.
- Scheffe, H (1959): The analysis of variance. John Wiley.
- Searle, S. R. and Khuri, A. I. (2017). Matrix Algebra Useful for Statistics, 2nd Ed., John Wiley, New York.
- Searle, S. R. (1971): Linear models. John Wiley.
- Shanti Narayan and Mittal, P. K. (2000): Textbook of Matrices. S. Chand and Company. New Delhi.
- Wang, S. G. and Chow, S. C. (1994): Advanced Linear Models. Marcel Dekker.

504: Statistical Inference – I

Programme Name:	M.Sc. Statistics	Course Code and Name:	504: Statistical Inference- I
Total Credits:	04	Total Marks:	100
University assessment:	50	College assessment:	50
Pre requisite: Concepts of estimation, properties of estimator, concepts of hypothesis, types of error, critical region, power function.			
Course outcomes: After completion of the course learners will, CO 1) Able to estimate unknown parameters of real life models. CO 2) Able to compute point estimate and interval estimate. CO 3) Know different methods of estimation. CO 4) Understand the properties of an estimator. CO 5) Know, fundamental concepts of testing of hypotheses. CO 6) Able to formulate statistical hypothesis in real life situations. CO 7) Able to develop best test procedures to test the hypothesis.			
MODULE I:			(2 CREDITS)
Unit 1:	a) Review of estimation theory, estimate, estimator, statistic, exponential family, m-parameter exponential family, Pitman family. b) Problem of point Estimation, sufficiency, Neymann factorization theorem, minimal sufficiency, completeness, ancillarity. c) Unbiasedness, uniformly minimum variance unbiased estimator, Rao-Blackwell theorem, Lehmann-Scheffe theorem, biased estimator,		

	Cramer-Rao lower bound.
Unit 2:	a) Methods of estimation: Method of moments, method of maximum Likelihood estimation (M.L.E.), restricted parameter space, inconsistent MLE. b) Properties of M.L.E, Scoring method, Large sample properties of MLE.
MODULE II: (2 CREDITS)	
Unit 3:	a) Review of fundamental notions of testing of hypothesis: Statistical hypothesis, simple and composite hypothesis, critical region, acceptance region, type I and type II errors, test function, test of hypothesis, power of test, power function. b) Best critical region, most powerful test, Neymann-Pearson lemma, uniformly most powerful (UMP) test, examples, non existence of UMP.
Unit 4:	a) Monotone likelihood ratio property of family of distributions, examples. b) Generalized Neymann-Pearson Lemma, Locally Most Powerful test (LMPT). Unbiased test, UMP unbiased test, Locally Most Powerful Unbiased test.
References: • Casella, G. and Berger, R. L. (2002): Statistical Inference. Duxbury. • Cox, D. R. and Hinkley, D. V. (1996): Theoretical Statistics. Chapman and Hall. • Dixit, U. J. (2016): Examples in Parametric Inference with R. Springer • Goon, A. M., Gupta, M. K. and Dasgupta, B. (1998): An outline of statistical theory. The World Press. Calcutta. Volume II. • Shao, J. (2005): Mathematical Statistics. Springer. 2nd Edition. • Kale, B. K. (2005): A First Course on Parametric Inference. Narosa Publishing • Lehmann, E.L. and Casella, G. (1998): Theory of point estimation. Springer. • Lehmann, E. L. and Romano, J. P. (2005): Testing Statistical Hypothesis, Springer. 3rd Edition. • Mood, A. M., Graybill, F. A. and Boes, D. C. (2005): Introduction to the theory of Statistics. Tata McGraw-Hill. Third edition. • Rajgopalan, M. and Dhanavanthan, P. (2012): Statistical Inference. PHI Learning, New Delhi. • Rohatgi V.K. and Saleh A.K. Md. Ehasanes (2001): An Introduction to Probability and Statistics. Wiley	

- Srivastava, M. K. and Srivastava, M. (2014): Statistical Inference: Testing of Hypotheses. PHI Learning private limited.

505: Statistics Practical - I

Programme Name:	M.Sc. Statistics	Course Code and Name:	505: Statistics Practical I
Total Credits:	02	Total Marks:	50
University assessment:	50	College assessment:	---
Pre requisite: Courses 502, 503, 504			
Course outcomes: After completion of the course learners will, CO 1) Able to solve problems based on sequence, series, matrix algebra. CO 2) Have introduction to R language. CO 3) Able to solve numerical problems based on one-way and two-way analysis of variance.			
MODULE I:			(2 CREDITS)
Unit 1:	Following practicals must be completed using calculator. 1) Problems based on sequence 2) Problems based on series. 3) Problems based on inverse of a matrix, rank of a matrix, echelon forms, canonical form. 4) Problems based on generalized inverse, solving linear equations. 5) Problems based on characteristic roots and characteristic vectors. 6) Problems based on estimability of parametric function, estimates of parametric function, Gauss-Markoff theorem. 7) Methods of estimation, variance bounds. 8) Testing of hypothesis: finding probabilities of type I, type II errors, power function, MP, UMP test.		
Unit 2:	Following practicals must be completed using R 9) Introduction to R Language, Data entry, Simple and matrix algebra using R Language. 10) Required packages or functions of R for completing following practicals. 11) Problems based on One –way analysis of variance model and checking assumptions of the model.		

	12) Two – way analysis of variance model with and without interaction effect, one observation per cell and r observations per cell. 13) Two – way analysis of variance model with and without interaction effect, with unequal number of observations per cell. 14) Analysis of variance with random and Mixed effect models and Analysis of Covariance.
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Elective Courses

E1 506 (A): Sampling Techniques

Programme Name:	M.Sc. Statistics	Course Code and Name:	E1 506(A): Sampling Techniques
Total Credits:	02	Total Marks:	50
University assessment:	25	College assessment:	25
Pre requisite: Probability sampling, simple random sampling, stratified random sampling.			
Course outcomes: After completion of the course learners will, CO 1) Know different probability sampling methods. CO 2) Able to decide proper random sampling method to obtain sample. CO 3) Able to obtain a random sample in real problems. CO 4) Able to estimate population mean and its standard error under different random sampling methods.			
MODULE I:			(2 CREDITS)
Unit 1:	a) Systematic random sampling when $N = nk$ and $N \neq nk$, estimation of population mean, different forms of variance of estimated population mean, comparison with simple random sampling and stratified random sampling in case of without replacement. b) Probability proportional to size sampling with replacement, Lahiri's and cumulative total methods, estimation of population mean, variance of estimated population mean and its estimate. Probability proportional to size sampling without replacement, Horvitz and Thompson estimator of population mean and its variance, Yates and Grundy form of variance.		
Unit 2:	a) Cluster sampling, estimation of population mean and its variance, comparison with simple random sampling without replacement. b) Two stage sampling (both the stages with SRSWOR), estimation of		

	population mean and its variance, Double sampling, estimation of population mean and its variance. c) Network sampling: multiplicity estimator, Horvitz-Thompson estimator, stratification in network sampling. Adaptive sampling:
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References:

- Bansal A, (2017): Survey Sampling. Narosa.
- Chaudhari, A and Stenger, H (1992): Survey Sampling, Marcel Dekker.
- Chaudhari, A (2014): Modern Survey Sampling, CRC Press.
- Cochran W.G. (1999): Sampling techniques. Wiley series.
- Singh, D. and Chaudhary, F. S. (1986): Theory and Analysis of Sample Survey Designs. New Age International Publishers.
- Mukhopadhyay, P. (2009): Theory and Methods of Survey Sampling. Eastern Economy Edition, 2nd Edition.
- Murthy, M.N.(1967): Sampling theory and Methods. Statistical Publishing Society, Calcutta.
- Sukhatme, P.V.and Sukhatme, B.V.(1970) : Sampling theory of Surveys with applications. Food and Agriculture organization.
- Thompson, S. K. (2002): Sampling. Willey. 2nd edition.

E1 506 (B): Statistics Practical II

Programme Name:	M.Sc. Statistics	Course Code and Name:	E1 506 (B): Statistics Practical II
Total Credits:	02	Total Marks:	50
University assessment:	50	College assessment:	---
Pre requisite: Course E1 506 (A)			
Course outcomes: After completion of the course learners will, CO 1) Able to generate random samples for real life situation. CO 2) Able to estimate population mean and its standard error. CO 3) Able to visualize statistical data using Tableau. CO 4) Able to use advanced excel to analyze data statistically.			
MODULE I:			(2 CREDITS)
Unit 1:	Following practicals must be completed using calculator / Excel, 1) Simple random sampling 2) Stratified random sampling		

	3) Systematic random sampling 4) Probability proportional to size sampling. 5) Cluster and two-stage sampling.
Unit 2:	35 sessions should be conducted on the following points , i. Different Visualization techniques of Tableau, Power BI, application of Tableau, Power BI in statistics. ii. Data editing and statistical techniques using Excel. iii. Data entry, data importing, exporting, elementary statistical analysis using SPSS, MINITAB.

E2 506 (A): Optimization Techniques

Programme Name:	M.Sc. Statistics	Course Code and Name:	E2 506 (A) : Optimization Techniques
Total Credits:	02	Total Marks:	50
University assessment:	25	College assessment:	25
Pre requisite: Linear programming problem, graphical method of solving linear programming problem, simplex method, Dual simplex method.			
Course outcomes: After completion of the course learners will, CO 1) Find optimum solution of a real valued non-linear function. CO 2) Find optimum solution of linear real valued function under constraints. CO 3) Find optimum solution of non-linear real valued function under constraints. CO 4) Find an optimal solution of an integer programming problem.			
MODULE I:			(2 CREDITS)
Unit 1:	a) Open and closed set in n-dimensional Euclidean space, convex set, Hyperplane. b) Review of Linear Programming Problem (LPP), basic solution, feasible solution, optimal solution, convexity of set of feasible solutions, optimal solution as extreme point of feasible space, simplex method, revised simplex method, theorems on duality, dual simplex method, Karmarkar interior point algorithm. c) Integer Linear programming: Gomory cut method, branch and bound method		
Unit 2:	a) Local and global extrema of a real valued function, unconstrained and constrained extrema of differentiable non-linear real valued function, method of Lagrange multipliers, convex function and its extrema, convex		

	programming problem. b) Kuhn-Tucker conditions of optimality, quadratic programming; methods due to Beale, Wolfe and Vandepanne. c) Grid search method, Hooke and Jeeves' method, steepest descent and Newton method for unconstrained optimization. Penalty method for constrained optimization.
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References:

- Hadley, G. (2002): Linear Programming. Narosa.
- Kambo, N. S. (2008): Mathematical Programming Techniques. Affiliated East West Press Pvt.
- Mittal, K. V. and Mohan, C. (1996): Optimization methods in operations research and system analysis. New Age International .Third edition.
- Rao, S. S. (2006): Engineering optimization: Theory and Practice. New Age International,
- Taha, H. A. (2010): Operations Research: An introduction. Pearson. 9th Edition.
- Winston, W. L. (2003): Operations Research: Applications and Algorithms. Cengage Learning. 4th Edition.

E2 506 (B): Statistics Practical II

Programme Name:	M.Sc. Statistics	Course Code and Name:	E2 506 (B): Statistics Practical II
Total Credits:	02	Total Marks:	50
University assessment:	50	College assessment:	---
Pre requisite: Course PSST E2 506 (A)			
Course outcomes: After completion of the course learners will, CO 1) Able to optimize a real valued function with or without constraints. CO 2) Able to visualize statistical data using Tableau. CO 3) Able to use advanced excel to analyze data statistically.			
MODULE :			(2 CREDITS)
Unit 1:	Following practicals must be completed using calculator. 1) Finding an optimal solution to LPP using graphical, simplex and revised simplex methods. 2) Integer programming problem. 3) Finding an optimal solution of a real valued non-linear function using		

	differential calculus and method of Lagrange multipliers. 4) Finding an optimal solution using Kuhn-Tucker conditions. 5) Optimization Problems based on Grid search method, Hooke and Jeeves' method, steepest descent, Newton method, Penalty method for constrained optimization. 6) Above practicals using R language / TORA.
Unit 2:	35 sessions should be conducted on the following points , i. Different Visualization techniques of Tableau, Power BI, application of Tableau, Power BI in statistics. ii. Data editing and statistical techniques using Excel. iii. Data entry, data importing, exporting, elementary statistical analysis using SPSS, MINITAB.

E3 506 (A): Basic Statistics for Data Analysis (for other than Statistics students)

Programme Name:	M.Sc. Statistics	Course Name:	E3 506 (A): Basic Statistics for Data Analysis
Total Credits:	02	Total Marks:	50
University assessment:	25	College assessment:	25
Pre requisite: NIL			
Course outcomes: After completion of the course learners will, CO 1) Understand different measurements and scaling. CO 2) Able to generate data using random sampling methods. CO 3) Able to represent data using suitable graph/diagram CO 4) Able to summarise data statistically.			
MODULE I:			(2 CREDITS)
Unit 1:	a) Introduction to Statistics, need of Statistics, measurement and scaling, scaling techniques, types of data, Statistics in scientific Research: research design, types of statistical research: empirical, field experiments, laboratory experiments. b) Data collection methods: population, sample, sampling frame, sampling unit, determination of sample size, generating a random sample using probability sampling methods as, simple random sample, stratified random sample with different allocations, systematic random		

	sample, multi-stage, multi-phase random sample, non-response and methods for recovering non-response. c) Univariate Data presentation: simple and multiple bar diagrams, pie diagram, histogram, frequency curve, stem-leaf display
Unit 2:	a) Summary statistics: mean, median, mode, harmonic mean, geometric mean, variance, coefficient of variation, mean deviation about median, mean deviation about mean, absolute mean, range, Box plot, violin plot. Examples, b) Raw and central Moments up to fourth order, symmetric frequency curves, asymmetric frequency curves, skewness, measures of skewness, kurtosis, measures of kurtosis
References: 1. Agarwal, B. L. (2013): Basic Statistics. New age International. 2. Anderson, D. R., Sweeny, D. J. and Williams-Rochester, T. A. (2002): Statistics for business and economics. Thomson Press. 3. Hanagal, D. D. (2017): Introduction to Applied Statistics: Non-Calculus Based Approach. Narosa Publishing House. 4. Hogg, R., Craig, A. T. and McKean, J. W. (1995): Introduction to Mathematical Statistics. Pearson. 6th Edition. 5. Kothari, C. R. (2014): Research Methodology. Third edition, Wiley Eastern limited. 6. Levin, R. I. and Rubin, D. S. (1998): Statistics for management. Pearson. 6th Edition. 7. Mood, A. M., Graybill, F. A. and Boes, D. C. (1973): Introduction to the theory of Statistics. McGraw –Hill. 3rd Edition. 8. Wackerly, D., Mendenhall, W. and Scheaffer, R. L. (2008): Mathematical Statistics with applications. Thomson. 7th Edition.	

E3 506 (B): Statistics Practical II

Programme Name:	M.Sc. Statistics	Course Code and Name:	E3 506 (B): Statistics Practical II
Total Credits:	02	Total Marks:	50
University assessment:	50	College assessment:	---
Pre requisite: Course PSST E3 506 (A)			
Course outcomes: After completion of the course learners will,			

CO 1) Able to use Excel, R Language.

CO 2) Able to represent data using suitable graph/diagram.

CO 3) Able to summarize data statistically.

MODULE I:

(2 CREDITS)

Unit 1:

- i. Sessions to introduce excel, SPSS, R Language: data entry, data importing, exporting, data editing.
- ii. Problems based on following topics should be covered using Excel, SPSS, R Language,
 - 1) Generating random sample.
 - 2) Representing data using graphs and diagrams
 - 3) Computations of summary statistics

EXAMINATION PATTERN FOR THEORY COURSES

Each course will be evaluated in two components,

Component A] Continuous Internal Evaluation (CIE) and

Component B] Semester End Examination (SEE)

CIE will be of 50 marks which will include,

- one test of 30 marks of one and half hour duration and
- other 20 marks are composed of any one or combinations of group discussion, presentation, viva-voce, open notebook test, surprise test, assignments, data analysis etc. to be conducted by respective teacher.

SEE will be a theory examination of 50 marks of two hours duration based on entire syllabus.

The question paper will consist of six questions of 10 marks each. Student should answer any five questions out of six questions.

EXAMINATION PATTERN FOR PRACTICAL COURSES

At the end of semester there will be a practical examination of 50 marks and of two hours duration for each of the practical course. The distribution of total of 50 marks is as given below,

Practical Examination	Viva	Journal	Total
40 marks	10 marks	Compulsory	50 marks

M.Sc. (Statistics) Part I
Semester II
Mandatory courses

507: Multivariate Analysis – I

Programme Name:	M.Sc. Statistics	Course Code and Name:	507: Multivariate Analysis – I
Total Credits:	04	Total Marks:	100
University assessment:	50	College assessment:	50
Pre requisite: 501, 502			
Course outcomes: After completion of the course learners will, CO 1) Know some standard multivariate distributions. CO 2) Able to visualize multivariate data. CO 3) Know multivariate normal distribution. CO 4) Able to check goodness of fit of multivariate normal distribution for the data. CO 5) Able to test the hypothesis for two or more normal populations. CO 6) Able to obtain multiple linear regression for multivariate data. CO 8) Know multiple and partial correlation coefficients and test their significance.			
MODULE I: (2 CREDITS)			
Unit 1:	a) Univariate non-central distributions: non-central chi-square, t, F distributions. b) Some standard multivariate distributions, Dirichlet distribution.		
Unit 2:	a) Multivariate data and Multivariate graphical display, mean vector, dispersion matrix, correlation matrix. b) Multivariate normal distribution, characteristic function, singular and non-singular normal distributions, distribution of a linear form and a quadratic form of normal variables, marginal and conditional distributions, Goodness of fit of multivariate normal distribution, MLE's of the parameters of multivariate normal distribution c) Wishart Distribution and its properties, sampling distributions of MLE's.		
MODULE II: (2 CREDITS)			
Unit 3:	a) Hotelling's T^2 -statistic and its application to test the hypothesis about the mean vector of a multivariate normal distribution in case of one and two samples, simultaneous confidence interval for the linear functions of the mean. b) Multiple linear regression and multiple and partial correlation coefficients among several variables, Tests of significance for multiple and partial		

	correlation coefficients.
Unit 4:	a) Likelihood Ratio Tests. b) Multivariate Analysis of variance.
References: - Anderson, T.W.(2004): An Introduction to Multivariate Statistical Analysis. John Wiley & Sons. Third edition. - Dillon, W. R. and Goldstein, M. (1984): Multivariate Analysis: Methods and Applications. - Giri, N. C. (1995): Multivariate Statistical Analysis. - Härdle, W. K., Hlávka, Z. (2007): Multivariate Statistics: Exercises and Solutions, Springer, New York - Johnson, R. A. and Wichern, D. W. (2002): Applied Multivariate Statistical Analysis, PHI Learning. 5th Edition. - Kotz, S., Balakrishnan N. and Johnson N. L. (2000): Continuous Multivariate Distributions, Volume 1, Models and Applications, John Wiley & Sons. - Kshirsagar, A. M. (1979): Multivariate Analysis, Marcel Dekker Inc. New York. - Morrison, D.F. (1990): Multivariate Statistical Methods, McGraw Hill Co. - Rao, C. R. (2002): Linear Statistical Inference and its Applications, Wiley Eastern - Timm, N. H. (2002): Applied Multivariate Analysis, Springer, New York	

508: General Linear Models

Programme Name:	M.Sc. Statistics	Course Code and Name:	508: General Linear Models
Total Credits:	04	Total Marks:	100
University assessment:	50	College assessment:	50
Pre requisite: Course 503			
Course outcomes: After completion of the course learners will, CO 1) Able to fit multiple linear regression models to real life data. CO 2) Able to check adequacy of the fitted model using residual analysis. CO 3) Able to apply general linear models such as logistic regression, Poisson regression to data.			
MODULE I:			(2 CREDITS)
Unit 1:	a) Multiple Linear regression models, estimation and testing of significance		

	of parameters. b) Regression diagnostics: definition of ordinary and studentized residuals, their properties and use in regression diagnostics, autocorrelation, influence analysis, Cook's distance, PRESS statistics, covariance ratio, orthogonal polynomials. Box-Cox Power transformation, Diagnostics of Multicollinearity. c) Sensitivity Analysis: Properties of Hat matrix, Role of variables in regression model.
Unit 2:	a) Regression on Dummy variable, variable selection methods: subset selection, Forward selection, backward elimination and stepwise regression. b) Generalized Linear models: link function, Logistic regression: Example, model, MLE of parameters, Iterative procedure to solve likelihood equations, multiple regressors, c) Multinomial and Ordinal Logistic Regression.
MODULE II: (2 CREDITS)	
Unit 3:	a) Poisson regression, binomial regression, gamma regression. b) Analysis of count data: Log linear models, Contingency tables.
Unit 4:	a) Ridge regression: Ill conditioned matrix, need of ridge regression, biased estimator. b) Mean square error, Bias and MSE of ridge estimator, ridge trace method.
References: • Agresti, A. (2002): Categorical data analysis. John Wiley, New York. • Chatterjee, S. and Hadi, A. S. (2012): Regression Analysis with example. John Wiley. • Cox, D. R. and Snell, E. J. (1989): Analysis of binary data. CRC Press. • Draper, N.R and Smith, H. (2003): Applied Regression Analysis. John Wiley. New York • Hosmer, D. W. and Lemeshow, S. (1989). Applied Logistic Regression, Wiley • Kleinbaum, D. G. And Klein, M. (2000): Logistic regression: A self-learning text. Springer • Montgomery, D. C., Peck, B.A. and Vining, G. G. (2003): Introduction to linear regression analysis. John Wiley. • Wang, S. G. and Chow, S. C. (1994): Advanced Linear Models: Theory and Applications. Marcel Dekker. • Sen, A and Srivastava, M. (1990): Regression analysis: Theory methods and	

applications. . Springer.

509: Statistical Inference – II

Programme Name:	M.Sc. Statistics	Course Code and Name:	509: Statistical Inference II
Total Credits:	04	Total Marks:	100
University assessment:	50	College assessment:	50
Pre requisite: Course 504, Concepts of estimation, properties of estimator, concepts of hypothesis, types of error, critical region, power function,			
Course outcomes: After completion of the course learners will, CO 1) Able to find consistent estimators for an unknown parameter. CO 2) Know, fundamental concepts of Bayesian inference. CO 3) Able to select best model using information criteria. CO 4) Able to obtain best confidence sets of unknown parameters.			
MODULE I:			(2 CREDITS)
Unit 1:	a) Consistency, properties of consistent estimators, Comparison of consistent estimators, minimum sample size required by the estimator to attain certain level of accuracy. b) Consistent and asymptotically normal (CAN) estimators for real and vector valued parameters, invariance property under continuous transformation.		
Unit 2:	a) Prior distribution, Posterior distribution, Bayes' estimator, Loss function, risk functions Minimavity and Admissibility. b) Posterior inference, Model selection and hypothesis testing based on Bayes' factor.		
MODULE II:			(2 CREDITS)
Unit 3:	c) Likelihood ratio test, information criterion for model comparison, AIC, AICc, BIC, DIC etc. d) Confidence sets: Uniformly Most Accurate (UMA), Uniformly Most Accurate Unbiased (UMAU) confidence sets. e) EM algorithm, Convergence of EM algorithm		
Unit 4:	a) Markov Chain Monte Carlo Methods, Metropolis-Hastings Algorithm, Gibbs sampling, examples, convergence and diagnostic issues b) Resampling techniques, Jackknife and Bootstrap Estimator, estimation of		

sampling distribution.

References:

- Bolstad, W. M. (2010): Understanding computational Bayesian statistics. John Wiley
- Bolstad, W. M. (2017): Introduction to Bayesian Statistics, 3rd Edition. John Wiley.
- Congdon, P. (2006): Bayesian Statistical Modeling, John Wiley.
- Cox, D. R. and Hinkley, D. V. (1996): Theoretical Statistics. Chapman and Hall.
- Davison, A.C. and Hinkley, D.V. (1997): Bootstrap methods and their Applications. Chapman and Hall.
- Dixit, U. J. (2016): Examples in Parametric Inference with R. Springer
- Efron, B. and Hastie, T. (2016): Computer Age Statistical Inference: Algorithms, Evidence and Data Science. Cambridge University Press.
- Gamerman, Dani (1997): Markov chain Monte Carlo: Stochastic simulation for Bayesian inference. Chapman and Hall.
- Gelman, A., Carlin, J. B., Stern, H. S. and Rubin, D. B. (2003): Bayesian Data Analysis, second edition. Chapman and Hall.
- Gilks, W. R., Richardson, S., and Spiegelhalter, D. (eds.) (1995): Markov Chain Monte Carlo in Practice. Chapman and Hall.
- Kale, B. K. (2005): A First Course on Parametric Inference. Narosa Publishing
- Kundu, D. and Basu, A. (2009): Statistical Computing: Existing Methods and Recent Developments. Narosa.
- Lehmann, E.L. and Casella, G. (1998): Theory of point estimation. Springer.
- McLachlan, G.J. and Krishnan, T. (2008): The EM Algorithms and Extensions. Wiley.

510: Statistics Practical - III

Programme Name:	M.Sc. Statistics	Course Code and Name:	510: Statistics Practical III
Total Credits:	02	Total Marks:	50
University assessment:	50	College assessment:	---
Pre requisite: Courses 507, 508, 509			
Course outcomes: After completion of the course learners will, CO 1) Able to find and test the significance of multiple and partial correlation coefficients for multivariate real life data. CO 2) Able to compare different models statistically.			

CO 3) Able to fit different regression models to real life data.	
MODULE I: (2 CREDITS)	
Unit 1:	Following practicals must be completed using calculator and or Excel 1) Multivariate normal distribution 2) Multiple linear regression, multiple and partial correlation coefficients. 3) Consistent estimator. 4) Bayesian estimation and model comparison. 5) Likelihood ratio test 6) Bayesian inference
Unit 2:	Following practicals must be completed using R Language 1) Required packages or functions of R for completing following practicals. 2) Multivariate normal distribution 3) Hotelling T^2 4) Multivariate analysis of variance 5) Likelihood ratio test 6) Multiple linear regression 7) Logistic regression 8) Ridge regression 9) General linear models

Elective Courses

E1 511 (A): Nonparametric Inference

Programme Name:	M.Sc. Statistics	Course Name:	E1 511: Nonparametric Inference
Total Credits:	02	Total Marks:	50
University assessment:	25	College assessment:	25
Pre requisite: Course 504, Hypothesis, types of errors, power function, critical region.			
Course outcomes: After completion of the course learners will, CO 1) Know, concept of U-statistics. CO 2) Able to test the hypothesis of equality of distribution functions for two and more samples using nonparametric tests. CO 3) Able to measure association between two attributes.			

MODULE I:		(2 CREDITS)
Unit 1:	a) Quantile, Quantile function, Empirical distribution function, Empirical quantile function. Point estimation and interval estimation of population quantiles. Test of hypotheses for population quantile. b) Kernel, symmetric kernel, U-statistics: definition, properties, one sample and two sample theorem, one and two sample problems. c) Sign test and Wilcoxon's test, Wald-Wolfowitz run test, Mann-Whitney U-test, Wilcoxon Rank-Sum test.	
Unit 2:	a) Test for equality of variances of k independent samples: Median test, Kruskal-Wallis test, Friedman test. b) Distribution free test, Goodness of fit tests: Chi-square goodness of fit test, Kolmogorov-Smirnov test. c) Sequential probability ratio test. d) Measures of association and their tests of significance. Kendall's Tau coefficient, Spearman's coefficient of rank correlation	
<u>References:</u> • Deshpande, J. V., Gore, A. P. And Shanubhogue, A. (1995): Statistical analysis of nonnormal data. New age International • Gibbons, J. D. and Chakraborti, S. (2010): Nonparametric Statistical Inference. CRC Press. 5th Edition. • Kale, B. K. (2005): A First Course on Parametric Inference. Narosa Publishing • Randles, R. H. and Wolfe, D. A. (1979): Introduction to the theory of nonparametric statistics. John Wiley. • Rohtagi, V. K. and A.K.M.AD. Ehsanes Saleh (2001): An Introduction to Probability and Statistics. John Wiley. 2nd Edition. • Wald, A. (1947): Sequential Analysis.		

E1 511 (B): Statistics Practical IV

Programme Name:	M.Sc. Statistics	Course Code and Name:	E1 511 (B): Statistics Practical IV
Total Credits:	02	Total Marks:	50
University assessment:	50	College assessment:	---
Pre requisite: Course E1 511 (A)			
Course outcomes: After completion of the course learners will,			

CO 1) Able to apply nonparametric tests to real life data.	
CO 2) Able to check goodness of fit of a distribution fitted to a real life data.	
CO 3) Able to measure association between two attributes.	
MODULE I: (2 CREDITS)	
Unit 1:	Following practicals must be completed using calculator. 1) One and two samples nonparametric tests. 2) k samples nonparametric tests. 3) Goodness of fit tests 4) Sequential probability ratio test. 5) Tests for Measures of association. 6) Above practicals using R language.
Unit 2:	35 sessions on Introducing R language and Latex typesetting. • Data editing, data managing, importing, exporting data, data visualization, statistical analysis using R language. • Latex typesetting: basics typing, creating tables, writing mathematical functions.

E2 511 (A): Statistical Process Control - I

Programme Name:	M.Sc. Statistics	Course Code and Name:	E2 511 (A): Statistical Process Control- I
Total Credits:	02	Total Marks:	50
University assessment:	25	College assessment:	25
Pre requisite: Quality, R chart, S chart, X-bar chart, n chart, np chart, c chart, u chart			
Course outcomes: After completion of the course learners will, CO 1) Understand concept of quality and total quality management. CO 2) Able to construct control charts univariate and multivariate process. CO 3) Able to identify whether real process is under control. CO 4) Carry out system capability analysis.			
MODULE I: (2 CREDITS)			
Unit 1:	a) Concept of quality, Need of quality control, roll of Statistics in process control, total quality management, quality control through testing of hypothesis, review of control charts: R chart, S chart, X-bar chart, control charts for individual measurements. n chart, np chart, c chart, u chart, control charts of variable sample size, OC function, ARL function of these		

	charts. b) Cumulative sum chart, Moving average control charts.
Unit 2:	a) Exponentially Weighted Moving Average Control Charts, Modified and Acceptance control charts. Group control charts for multiple-stream processes. b) SPC with correlated data, Multivariate quality Control. c) Process and Measurement System Capability Analysis: Capability indices C_p , C_{pk} , and C_{pm} ; estimation. confidence intervals and test of hypotheses.

References:

1. Duncan, A. J. (1986): Quality Control and Industrial Statistics. Irwin. 5th Edition.
2. Grant, E. L. and Leavenworth, R. (2017): Statistical Quality Control. McGraw Hill. 7th Edition.
3. Montgomery, D. C. (2004): Introduction to Statistical Quality Control. John Wiley. 4th Edition.
4. Phadke, M. S. (1989): Quality Engineering Using Robust Design. Pearson.
5. Taguchi, G. (1986): Introduction to Quality Engineering: Designing quality into products and processes. Quality resources.

E2 511 (B): Statistics Practical IV

Programme Name:	M.Sc. Statistics	Course Code and Name:	E2 511 (B): Statistics Practical IV
Total Credits:	02	Total Marks:	50
University assessment:	50	College assessment:	---
Pre requisite: Course E2 511 (A)			
Course outcomes: After completion of the course learners will, CO 1) Able to draw control charts. . CO 2) Able to find capability indices. CO 3) Able to examine whether engineering process is under control or not.			
MODULE I:			(2 CREDITS)
Unit 1:	Following practicals must be completed using calculator and R language. 1) Draw R chart, S chart, X-bar chart, n chart, np chart, c chart, u chart. 2) Finding OC function, ARL function of these charts. 3) Draw Cumulative sum chart, Moving average control charts, Exponentially Weighted Moving Average Control Charts,		

	4) Draw Modified and Acceptance control charts, Group control charts, multivariate control charts. 5) Estimation, confidence intervals and test of hypotheses of Capability indices.
Unit 2:	35 sessions on Introducing R language and Latex typesetting. - Data editing, data managing, importing, exporting data, data visualization, statistical analysis using R language. - Latex typesetting: basics typing, creating tables, writing mathematical functions.

E3 511 (A): Operations Management

Programme Name:	M.Sc. Statistics	Course Code and Name:	E3 511 (A): Operations Management
Total Credits:	02	Total Marks:	50
University assessment:	25	College assessment:	25
Pre requisite: ---			
Course outcomes: After completion of the course learners will, CO 1) Understand concept of inventory management, inventory control, CO 2) Able to provide optimum inventory models. CO 3) Understand concepts of queuing theory.			
MODULE I:			(2 CREDITS)
Unit 1:	a) Inventory Management: Introduction to Inventory control problem, Type of Inventory, Different cost in Inventory Problem, Selective control techniques b) Techniques of Inventory models: EOQ with known demand, uniform demand, problem of EOQ with shortages, Inventory model with stochastic demand, Buffer stock, price discounts, back order inventory models		
Unit 2:	a) Queuing theory: Introduction of Queuing theory, Elements of a Queuing model. b) Pure birth and death model, specialized poison queues, single server models: (M/M/1):(GD/∞/∞), M/M/1:(GD/M/∞), Multiserver models. c) Data Envelopment Analysis (DEA) : meaning and use of DEA.		
References: • Gross, D. and Harris, C. M. (2002): Fundamentals of queueing theory. John Wiley.			

- Kambo, N. S. (2008): Mathematical Programming Techniques. Affiliated East West Press Pvt.
- Taha, H. A. (2010): Operations Research: An introduction. Pearson. 9th Edition.
- Winston, W. L. (2003): Operations Research: Applications and Algorithms. Cengage Learning. 4th Edition.
- Swarup, K., Gupta, P. K. and Mohan, M. (1992): Operations Research. Sultan Chand and Sons.

E3 511 (B): Statistics Practical IV

Programme Name:	M.Sc. Statistics	Course Code and Name:	E3 511 (B): Statistics Practical IV
Total Credits:	02	Total Marks:	50
University assessment:	50	College assessment:	---
Pre requisite: Course E3 511 (A)			
Course outcomes: After completion of the course learners will, CO 1) Able to determine solution to different inventory problems. CO 2) Able to solve queueing problems.			
MODULE I:			(2 CREDITS)
Unit 1:	Following practicals must be completed using calculator and or Excel. 1) Problems based on deterministic inventory models 2) Problems based on stochastic inventory models 3) Problems based on Pure birth and death model 4) Single server model 5) Multi server model		
Unit 2:	35 sessions on Introducing R language and Latex typesetting. • Data editing, data managing, importing, exporting data, data visualization, statistical analysis using R language. • Latex typesetting: basics typing, creating tables, writing mathematical functions.		

E4 511 (A): Elementary Statistics for Data Analysis (for other than Statistics students)

Programme Name:	M.Sc. Statistics	Course Code and Name:	E4 511 (A): Elementary Statistics for Data Analysis
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Total Credits:	02	Total Marks:	50
University assessment:	25	College assessment:	25
Pre requisite: Course E3 506 (A), measurement and scaling, scaling techniques, types of data, random sampling methods, summary statistics.			
Course outcomes: After completion of the course learners will, CO 1) Able to find probability of an event. CO 2) Know, concept of random variable, probability function. CO 3) Know, standard statistical distributions. CO 4) Able to estimate unknown parameters. CO 5) Able to test hypothesis.			
MODULE I:			(2 CREDITS)
Unit 1:	a) Random experiment, sample space, concept of probability, examples, conditional probability, Bayes' theorem, notion of random variable, probability function, distribution function, independence, mean, variance of random variable, examples. b) Standard discrete and continuous distributions: Bernoulli, binomial, Poisson, exponential, normal, chi-square, students t, F, applications of central limit theorem.		
Unit 2:	a) Estimation: need of estimation, notion of statistic, random sample, likelihood function, introduction to methods of estimation: maximum likelihood estimation, method of moments, properties of estimators. b) Testing of hypothesis: notion of hypothesis, one sided, two sided hypothesis, critical region, types of errors, test of hypothesis, parametric tests: t, chi-square, F, large sample tests. c) Nonparametric inference and its need, One sample, two sample nonparametric tests: sign test, Wilcoxon signed rank test, Mannn-Whitney U statistic.		
References: 1. Agarwal, B. L. (2013): Basic Statistics. New age International. 2. Anderson, D. R., Sweeny, D. J. and Williams-Rochester, T. A. (2002): Statistics for business and economics. Thomson Press. 3. Hanagal, D. D. (2017): Introduction to Applied Statistics: Non-Calculus Based Approach. Narosa Publishing House.			

4. Hogg, R., Craig, A. T. and McKean, J. W. (1995): Introduction to Mathematical Statistics. Pearson. 6th Edition.
5. Kothari, C. R. (2014): Research Methodology. Third edition, Wiley Eastern limited.
6. Kulkarni, M. B., Ghatpande, S. B. and Gore, S. D. (1999): Common Statistical tests. Satyajeet Prakashan, Pune.
7. Levin, R. I. and Rubin, D. S. (1998): Statistics for management. Pearson. 6th Edition.
8. Mood, A. M., Graybill, F. A. and Boes, D. C. (1973): Introduction to the theory of Statistics. McGraw –Hill. 3rd Edition.
9. Wackerly, D., Mendenhall, W. and Scheaffer, R. L. (2008): Mathematical Statistics with applications. Thomson. 7th Edition.

E4 511 (B): Statistics Practical IV

Programme Name:	M.Sc. Statistics	Course Code and Name:	E4 511 (B): Statistics Practical II
Total Credits:	02	Total Marks:	50
University assessment:	50	College assessment:	---
Pre requisite: Course E4 511 (A)			
Course outcomes: After completion of the course learners will, CO 1) Able to use Excel, R Language. CO 2) Able to estimate an unknown parameter. CO 3) Able to apply parametric tests to real life data.			
MODULE I:			(2 CREDITS)
Unit 1:	Following practicals should be completed using calculator and or Excel - Simple problems of probability, conditional probability, Bayes' theorem. Problems based on following topics should be covered using Excel, SPSS, R Language, - Finding probabilities. - Plotting probability mass/density functions. - Estimate the parameter. - Test the hypothesis using t, chi-square, F tests. - Large sample tests. - Nonparametric tests.		

EXAMINATION PATTERN FOR THEORY COURSES

Each course will be evaluated in two components,

Component A] Continuous Internal Evaluation (CIE) and

Component B] Semester End Examination (SEE)

CIE will be of 50 marks which will include,

- one test of 30 marks of one and half hour duration and
- other 20 marks are composed of any one or combinations of group discussion, presentation, viva-voce, open notebook test, surprise test, assignments, data analysis etc. to be conducted by respective teacher.

SEE will be a theory examination of 50 marks of two hours duration based on entire syllabus.

The question paper will consist of six questions of 10 marks each. Student should answer any five questions out of six questions.

EXAMINATION PATTERN FOR PRACTICAL COURSES

At the end of semester there will be a practical examination of 50 marks and of two hours duration for each of the practical course. The distribution of total of 50 marks is as given below,

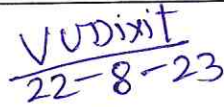
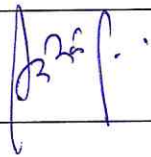
Practical Examination	Viva	Journal	Total
40 marks	10 marks	Compulsory	50 marks

LETTER GRADES AND GRADE POINTS

Semester GPA / Program CGPA Semester / Program	Percentage of Marks	Alpha-sign / Letter Grade Result
09.00 – < 10.00	90.00 – 100	O (Outstanding)
08.00 – < 09.00	80.00 - < 90.00	A+ (Excellent)
07.00 – < 08.00	70.00 - < 80.00	A (Very Good)
06.00 – < 07.00	60.00 - < 70.00	B+(Good)
05.50 – < 06.00	55.00 - < 60.00	B (Above Average)
05.00 - < 05.50	50.00 - < 55.00	C (Average)
04.00 – < 05.00	40.00 - < 50.00	P (Pass)
Below 04.00	Below 40.00	F (Fail)
Absent	---	Absent

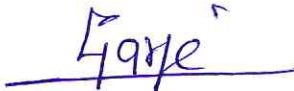
Syllabus
M.Sc. (Statistics)
(Sem. I & II)

Team for Creation of Syllabus

Name	College Name	Sign
Dr.(Mrs.) V. U. Dixit	Department of Statistics, University of Mumbai	 22-8-23
Prof. Santosh P. Gite	Department of Statistics, University of Mumbai	
Dr. Alok D. Dabade	Department of Statistics, University of Mumbai	


Signature of HOD
Prof. S. P. Gite
Head of the Statistics Department

DR. S. P. GITE
Head Department of Statistics
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Signature of Dean,
Prof. Shivram S. Garje
Science Faculty

Appendix-B

Justification for M.Sc. (Statistics)

1.	Necessity for starting the course:	Now days Statistics is required to analyze data in every field. This program accentuates both the core and modern applications of Statistics. The program is structured so that students will have in depth knowledge of Statistics for pursuing their higher studies and also necessary skills in statistics for the employability in corporate.
2.	Whether the UGC has recommended the course:	Yes
3.	Whether the course have commenced from the academic year 2022-23.	The course has already commenced from the academic year 1948 and in academic year 2022-23, it is restructured under NEP, 2020.
4.	The course started by the university is self-financed, whether adequate number of eligible permanent faculties is available?	This course is not self-financed. Currently three permanent faculty members are working in the department out of ten sanctioned faculty positions.
5.	To give details regarding the duration of the course and is it possible to compress the course?	Duration of the program is two years (four semesters). It is not possible to compress the course. Under NEP, 2020 students have option of exit at the end of first year with PG Diploma in Statistics.
6.	The intake capacity of each course and number of admissions given in the current academic year;	The intake capacity of program is 60. Number of admissions for the academic year 2022-23 is 60.
7.	Opportunity of Employability / Employment available after undertaking these courses:	There is a good opportunity for employment. Students have employability in education and research. Also they can get employment in corporate, multinational companies as a statistician, like finance, banks sector, pharmaceutical sector, IT sector etc.


Signature of HOD
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