PRESIDENCY
UNIVERSITY
KOLKATA

Presidency University, Kolkata
Syllabus
in
M.Sc. Statistics
Semesters 7 – 10
(With Effect from Academic Session 2021 – 2022)

Department of Statistics
(Faculty of Natural and Mathematical Sciences)
Presidency University
Previously Hindu College (1817 – 1855),
Presidency College (1855 – 2010)
86/1, College Street, Kolkata – 700 073
West Bengal, India

CONTENT

	STAT1092 : Research Project	21
	List of Topics to be Covered under Elective/Special Courses/Papers	
	Visualization and Analysis of Big and Complex Data	
	Data Analysis Using Python and C/C++	
	Advanced Mathematics	
	Analysis of Directional Data and Data on Manifolds	
	Statistics on Graphs and Networks	
	Analysis of High Dimensional Data	
	Machine Learning : Theory and Methods	
	Optimization Techniques and Operations Research/Convex Optimization	
	Advanced Sample Survey	
	Advanced Design of Experiments	
	Advanced Reliability Theory	
	Advanced Survival Analysis	
	Advanced Clinical Trials and Bioassay	
	Statistical Genetics and Epidemiology	
	Actuarial Statistics	
	Applied Stochastic Processes	
	Stochastic Calculus and Financial Engineering	
	Functional Data Analysis and Topological Data Analysis	
	Signal, Image, Video Data Processing and Analysis	
	Data Mining	

1.1 Academic Sessions :
Odd Semester : Semester Seven/Nine
Even Semester : Semester Eight/Ten

1.2 Major Courses/Papers

STAT0701 : Mathematics I	SEM 7
STAT0702 : Probability I	SEM 7
STAT0703 : Inference I	SEM 7
STAT0801 : Mathematics II	SEM 8
STAT0802 : Probability II	SEM 8
STAT0803 : Inference II	SEM 8
STAT0901 : Stochastic Processes	SEM 9
STAT0902 : Decision Theory and Bayesian Inference	SEM 9
STAT0903 : Inference III	SEM 9
STAT1001 : Special Paper	SEM 10
STAT1002 : Special Paper	SEM 10
STAT1003 : Research Methodology Nonparametric and Sequential Inference	SEM 10

1.3 Practical/Sessional Courses/Papers

STAT0791 : Regression I	SEM 7
STAT0792 : Statistical Computing	SEM 7
STAT0891 : Regression II	SEM 8
STAT0892 : Sample Survey and Design of Experiments	SEM 8
STAT0991 : Analysis of Time Series and Spatial Data	SEM 9
STAT0992 : Applied Multivariate Analysis and Resampling	SEM 9
STAT1091 : Combined Lab for **STAT1001, STAT1002** and **STAT1003**	SEM 10
STAT1092 : Project	SEM 10

In the tenth semester, a student will have to choose two special papers and the project, which is compulsory. Before the commencement of the semester, the department will announce the particular special paper(s) that may be offered depending upon the availability of faculty and resources.

Scheme for Courses in M.Sc. Statistics

1.4 Credit Distribution across Courses

Course Type	Total Papers	Credits (Theory+Practical)
Major Courses/Papers	12	12×4+12x0 = 48
Practical/Sessional Courses/Papers	8	8×2+8×2 = 32
Total	20	80

1.5 Scheme for M.Sc. Curriculum

Semester	Course/Paper	Paper Code	Course Name	IA Marks	Semester Marks	Total Marks
VII	Major Course - 17	STAT0701	Mathematics I	15	35	50
	Major Course - 18	STAT0702	Probability I	15	35	50
	Major Course - 19	STAT0703	Inference I	15	35	50
	Practical/Sessional Course - 9	STAT0791	Regression I	0	50	50
	Practical/Sessional Course - 10	STAT0792	Statistical Computing	0	50	50
VIII	Major Course - 20	STAT0801	Mathematics II	15	35	50
	Major Course - 21	STAT0802	Probability II	15	35	50
	Major Course - 22	STAT0803	Inference II	15	35	50
	Practical/Sessional Course - 11	STAT0891	Regression II	0	50	50
	Practical/Sessional Course - 12	STAT0892	Sample Survey and Design of Experiments	0	50	50
IX	Major Course - 23	STAT0901	Stochastic Processes	15	35	50
	Major Course - 24	STAT0902	Decision Theory and Bayesian Inference	15	35	50
	Major Course - 25	STAT0903	Inference III	15	35	50
	Practical/Sessional Course - 13	STAT0991	Analysis of Time	0	50	50

			Series and Spatial Data			
	Practical/Sessional Course - 14	STAT0992	Applied Multivariate Analysis and Resampling	0	50	50
X	Major Course - 26	STAT1001	Special Paper	15	35	50
	Major Course - 27	STAT1002	Special Paper	15	35	50
	Major Course - 28	STAT1003	**Research Methodology** Nonparametric and Sequential Inference	15	35	50
	Practical/Sessional Course - 15	STAT1091	Combined Lab for **STAT1001, STAT1002** and **STAT1003**	0	50	50
	Practical/Sessional Course - 16	STAT1092	Project	0	50	50

N.B:-
1. The lecture hours calculation in all the papers includes both theory and practical/ tutorial classes.
2. Use of suitable software such as MS-EXCEL/ MINITAB/ SPSS or similar others, depending on the availability of faculty and resources for all the core practical courses.

Lecture Hours Calculations:

1 credit of Theory / Tutorial = 1 Lecture
1 credit of Practical = 2 Lectures
Maximum number of effective class-weeks in a semester (excluding internal exams): 12 weeks
(Two weeks for mid-semester examination and sessional examination)

Total number of Lectures for a paper in a semester

Course	Credits (Theory+Practical)	Classes/week	Total lectures/semester
Major	4+0	(4×1) + (0×2)	48
Practical/Sessional	2+2	(2×1) + (2×2)	72

2.

Detailed Syllabus of Courses in M.Sc. Statistics

Semester	**SEVEN**
Paper	**Major Course - 17**
Paper Code	**STAT0701**
Paper Title	**Mathematics I**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Recap of Functions, Cardinality of Sets, Cantor's Theorem. Field and Order properties of real numbers, The Completeness Axiom of R, Archimedean property, Origin of Irrational numbers, Comparison of R and Q, Denseness of Rational numbers in R.
	Unit 2 Recap of Sequence and Series of real numbers, tests of convergence, rearrangement of series and Riemann's theorem (without proof) and its importance. Limits and Continuity, Properties of Continuous functions. Uniform and absolute continuity.
	Unit 3 Recap of Differentiation, Rolle's theorem and mean value theorem,Taylor series with remainder and infinite Taylor series. Recap of Riemann Integration, First and Second Fundamental theorems of Integral Calculus, Mean Value theorem for Integrals.
	Unit 4 Definition of metric space, Examples, Some Topological aspects, Convergence of Sequences in metric spaces, Cauchy Sequences and Completeness, Continuity and Uniform Continuity, Compactness, Heine-Borel Theorem.
Reading/ Reference Lists	Bartle, R. G. & Sherbert, D. R. : Introduction to Real Analysis Apostol, T.M. : Mathematical Analysis Rudin, W. : Principles of mathematical analysis Malik, S.C. & Arora, S. : Mathematical Analysis Kumaresan, S. : A Basic Course in Real Analysis Chakraborty, A. : Real Analysis, volumes 1,2,3 (2014), second edition, Sarat Book House. Simmons, G. F. : Introduction to Topology and Modern Analysis

Semester	**SEVEN**
Paper	**Major Course - 18**
Paper Code	**STAT0702**
Paper Title	**Probability I**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0

Syllabus	**Unit 1** Axiomatic definition of probability. Different classes of sets – semifield, field, sigma-field, Borel sigma-field, extension of measure from semifield to field. Good Sets principle, Caratheodory's extension and extension of measure from field to sigma-field.
	Unit 2 Cumulative distribution function and one to one correspondence between CDF and probability measures on Borel sigma-field on R. CDF and probability measures on Borel sigma-field on Rn. Measurable functions (random variables), basic properties, sigma-fields generated by functions, Lebesgue integration of measurable functions, properties of integrals, relation between Riemann and Lebesgue integral, Monotone convergence theorem, Fatou's Lemma, Dominated convergence theorem.
	Unit 3 Product measures, classical and general version of product measure theorem, Fubini's theorem (statement only), countable and uncountably infinite product of probability spaces and product measure theorem on them, Kolmogorov consistency theorem (statement only).
	Unit 4 Absolute continuity, singularity of measures, Radon-Nikodym theorem (statement only), Lebesgue decomposition (statement only).
Reading/ Reference Lists	Ash, R. B. & Doleans-Dade, C. A. : Probability and Measure Theory Chung, K. L. : A Course in Probability Theory Billingsley, P. : Probability and Measure Chow, Y. S. & Teicher, H. : Probability Theory Durrett, R. : Probability: Theory and Examples

Semester	**SEVEN**
Paper	**Major Course - 19**
Paper Code	**STAT0703**
Paper Title	**Inference I**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Review of concept of population and sample, family of probability measures, parameter and statistic, problems of inference. Exponential family, location and scale families.
	Unit 2 Non-central $\chi 2$, t & F distributions – definitions and selected properties. Distribution of quadratic forms – Cochran's theorem. Sampling from Multivariate normal distribution – independence of sample mean vector and variance covariance matrix. Wishart distribution. Distributions of partial and multiple correlation coefficients and regression coefficients, distribution of intraclass correlation coefficient.
	Unit 3 Review of Sufficiency principle, Minimal Sufficiency, Complete and boundedly complete families, Ancillarity and Basu's Theorem. Fisher information in case of single and multiple parameters, Cramer-Rao lower bound, Bhattacharya system of bounds. Review of unbiased estimation, Rao-Blackwell and Lehmann-Scheffe Theorems, Minimum Variance Unbiased Estimators and related problems.
	Unit 4 Review of methods of estimation, Maximum likelihood estimation in case of multivariate normal, Shrinkage Estimators of mean - James Stein's Estimate.

	Invariance estimation.
Reading/ Reference Lists	Lehmann. E.L., Casella, G. : Theory of Point Estimation Casella , G. and Berger R.L. : Statistical Inference Bickel, P.J., Doksum, K.A.: Mathematical Statistics: Basic Ideas and Selected Topics, Volume 1 Zacks, S : The Theory of Statistical Inference Rao, C.R. : Linear Statistical Inference and its Applications Shao, J. : Mathematical Statistics Anderson, T.W. : An Introduction to Multivariate Analysis. Khirsagar, A.M. : Multivariate Analysis Wilks, S.S.: Mathematical Statistics.

Semester	**EIGHT**
Paper	**Major Course - 20**
Paper Code	**STAT0801**
Paper Title	**Mathematics II**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	
	Unit 1 Sequences of real valued functions, Notions of Pointwise and Uniform convergence, Series of functions, Power series and their convergence. Weierstrass approximation theorem (without proof). Interchange of order of derivative and limits, Interchange of order of integration and limits.
	Unit 2 Partial Derivative, Directional derivative and Total derivative, Multivariate Taylor series expansion. Leibnitz theorem. Maxima and minima of multivariable functions.
	Unit 3 Recap of axiomatic approach to vector spaces, inner product space and normed linear space. Orthogonal polynomials, Fourier series representation of real and complex valued functions, Fourier series as best approximation, recovery of periodic functions using Fourier series, Carleson's theorem. Derivation of Fourier series of standard functions and related problems. Application of Fourier transform and Laplace transform.
	Unit 4 Concept of classical function spaces and sequence spaces. Banach space and Hilbert space.Complete orthonormal system (CONS), Reisz representation theorem (statement and application only), projection on Hilbert sub spaces and its properties. Lp space of random variables. L2 space of random variables and projection **-** illustrations using regression and other statistical examples.
Reading/ Reference Lists	Bartle, R. G. & Sherbert, D. R.: Introduction to Real Analysis Apostol, T.M. : Mathematical Analysis Rudin, W. : Principles of mathematical analysis

	Malik, S.C. & Arora, S. : Mathematical Analysis Kumaresan, S : A Basic Course in Real Analysis Chakraborty, A. : Real Analysis, volumes 1,2,3, second edition (2014), Sarat Book House. Rao, A.R. & Bhimasankaram, P. : Linear Algebra Folland, G.B. : Fourier Analysis and Its Applications Tolstov, G. P. : Fourier Series Stein, E. M., Stein, M. Shakarchi, R. : Fourier Analysis An Introduction Simmons, G. F. : Introduction to Topology and Modern Analysis Conway, J. B. : A Course in Functional Analysis Kreyszig, E. : Introductory Functional Analysis with Applications Rudin, W. : Functional Analysis

Semester	**EIGHT**
Paper	**Major Course - 21**
Paper Code	**STAT0802**
Paper Title	**Probability II**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Characteristic functions and its basic properties, inversion formula, Levy's continuity theorem. Kolmogorov's maximal inequality, Chebyshev's, Holder's and Minkowski's inequalities., Lp spaces. limsup, liminf and limit of sets, continuity from above and below, Borel-Cantelli two lemmas, Kolmogorov 0-1 law, sequence of random variables.
	Unit 2 Different modes of convergence and their interrelationships, properties and alternative characterizations, Slutsky's theorem, uniform convergence, Polya's theorem, Scheffe's theorem, Frechet-Shohat theorem (without proof), continuous mapping theorem, Uniform Integrability. Law of convergence of types, asymptotic normality, Cramer-Wold device, Skorohod representation theorem (application only).
	Unit 3 SLLN, WLLN, Lp-LLN, classical limit theorems, Different limit theorems for independent random variables and double arrays of random variables, partial sums of random variables and Kolmogorv 2 series and 3 series theorem.
	Unit 4 Introduction to discrete time stochastic process, discrete time discrete state space Markov chain, Chapman-Kolmogorov equation, renewal equation, classification of states, stationary distribution, limit distribution, ergodicity, null and positive recurrence, periodicity.
Reading/ Reference Lists	Ash, R. B. & Doleans-Dade, C. A. : Probability and Measure Theory Chung, K. L. : A Course in Probability Theory Billingsley, P. : Probability and Measure Chow, Y. S. & Teicher, H. : Probability Theory Durrett, R. : Probability: Theory and Examples Goswami, A. & Rao, B. V. : A course in applied stochastic process Medhi, J. : Stochastic Processes

Semester	**EIGHT**
Paper	**Major Course - 22**
Paper Code	**STAT0803**
Paper Title	**Inference II**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	
	Unit 1 Review of basic concepts of testing of hypothesis and confidence interval. Review of small sample exact tests and related confidence intervals, Beherens-Fisher problem (Scheffe's solution), likelihood ratio test and asymptotic chi-square tests. Wald's test and Rao's Score test. Review of F test for general linear hypothesis in case of linear models. Application of ANOVA technique in general linear hypothesis. Hotelling T-squared tests and related confidence sets, Union-intersection principle and its application.
	Unit 2 Review of notions of nonrandomized and randomized tests. Fundamental Neyman Pearson Lemma (Proof: Existence, Sufficiency and Necessity parts) and its generalization (Sufficiency part only), UMP Tests and related problems, Monotone Likelihood ratio.
	Unit 3 UMPU Tests: One parameter exponential family (without derivation), Locally best tests(Concepts only) Similar tests, Neyman structure, UMPU tests for composite hypotheses and related problems, Invariant tests: UMPI (concepts only).
	Unit 4 Interval estimation : Confidence sets based on pivot, relation with hypothesis testing, UMA and UMAU confidence sets.
Reading/ Reference Lists	Lehmann. E.L., Romano, J. : Testing statistical hypotheses. Casella , G. and Berger R.L. : Statistical Inference Bickel, P.J., Doksum, K.A.: Mathematical Statistics: Basic Ideas and Selected Topics, Volume 1 Zacks, S : The Theory of Statistical Inference Rao, C.R. : Linear Statistical Inference and its Applications Shao, J. : Mathematical Statistics Anderson, T.W. : An Introduction to Multivariate Analysis. Giri, N.C.: Multivariate Statistical Analysis. Seber, G.A.F and Lee, A.J. : Linear regression analysis.

Semester	**NINE**
Paper	**Major Course - 23**
Paper Code	**STAT0901**
Paper Title	**Stochastic Processes**
No. of Credits	**4**

No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Branching process, Introduction to continuous time stochastic process. Continuous time markov chains with discrete state space, Kolmogorov equations (applications only), birth and death chains, applications to queuing theory, busy period analysis, network of queues.
	Unit 2 Poisson process, equivalence of various constructions, basic properties, conditional distribution of arrival times given number of events and its applications, compound Poisson process, nonhomogeneous Poisson process, Poisson process on plane (concepts only).
	Unit 3 Introduction to Brownian motion, Kolmogorv continuity theorem, Donsker's invariance principle, other construction of Brownian motion, Brownian bridge, supremum of Brownian bridge and its application to goodness of fit tests.
	Unit 4 Conditional expectation and conditional probability distribution. Regular conditional probability (concept only). Discrete parameter martingales, sub-and super-martingales, martingale convergence theorem, reverse martingales, Stopping times, applications of martingale theory.
Reading/ Reference Lists	Ross, S. : Stochastic Processes Hoel, Port & Stone : Stochastic Processes Karlin, S. & Taylor, H. M. : Stochastic Processes Harris : Branching Processes: Harris Chow,Y. S. & Teicher, H. : Probability Theory Breiman, L. : Probability Theory Morters, P. & Peres, Y. : Brownian Motion Nevue, J. : Discrete Parameter Martingales Hall, P. & Heyde, C. C. : Martingale Limit Theory and its Application

Semester	**NINE**
Paper	**Major Course - 24**
Paper Code	**STAT0902**
Paper Title	**Decision Theory and Bayesian Inference**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Decision Problem and two-person game, nonrandomized and randomized rules, risk function, admissibility of decision rules, complete, essentially complete, minimal complete and minimal essentially complete classes. Essential completeness and completeness of class of rules based on sufficient statistic and the class of nonrandomized rules for convex loss.
	Unit 2 Bayes rules, extended Bayes, generalized Bayes and limit of Bayes rules, admissibility of Bayes rule, minimax rules, method for finding minimax rules.
	Unit 3 Bayesian Inference – difference with classical approach, point estimation and credible

	sets. Predictive distributions. Illustration with examples of one-parameter and multiparameter models using conjugate and noninformative priors. Bayesian testing and model selection. BIC. Objective Bayes factors, intrinsic priors.
	Unit 4 Bayesian variable selection, comparison of p-value and posterior probability of H0 as measures of evidence. Bayesian p-value. Bayesian approaches to some common problems in inference including linear regression. Hierarchical and empirical Bayes. Brief discussions on Bayesian computational techniques and their applications : Gibbs sampler and MH algorithm.
Reading/ Reference Lists	Ferguson, T. S. : Mathematical Statistics Berger, J. O. : Statistical Decision Theory and Bayesian Analysis Lehmann, E. L. : Theory of Point Estimation Robert, C. P. : The Bayesian Choice Ghosh, J. K., Delampady, M. & Samanta, T. : An Introduction to Bayesian Analysis: Theory and Methods. Lee, P. : Bayesian Statistics – An Introduction Congdon, P. : Bayesian Statistical Modelling (2nd Edition) Gelman, et.al. : Bayesian Data Analysis (3rd Edition). Hoff, P. D. : A First Course in Bayesian Statistical Methods.

Semester	**NINE**
Paper	**Major Course - 25**
Paper Code	**STAT0903**
Paper Title	**Inference III**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Asymptotic distribution of transformed statistics. Multivariate delta method and variance stabilizing formula and applications, asymptotic distribution of order statistics including extreme order statistics and sample quantiles. Asymptotic representation of sample quantiles.
	Unit 2 Large sample properties of maximum likelihood estimates and the method of scoring. Pearson's chi-square statistic. Chi-square and likelihood ratio test statistics for simple hypotheses related to contingency tables. Heuristic proof for composite hypothesis with contingency tables as examples. Brief introduction to asymptotic efficiency of estimators. ARE for comparison of tests.
	Unit 3 Basic idea of robustness, measures of robustness – breakdown points, influence function, sensitivity curve, M estimators, influence function of M estimators, different statistical models and associated robust statistics.
	Unit 4 Multiple comparison problem, simultaneous confidence intervals in linear models, multiple comparison tests in linear models, Tukey’s HSD, Fisher’s LSD, Scheffe’s test. Bonferroni correction, FDR and FWER with applications.
Reading/ Reference Lists	R.J.Serfling : Approximation Theorems of Mathematical Statistics E.L.Lehmann : Large Sample Theory C.R.Rao : Linear Statistical Inference and its Applications

	Jun Shao : Mathematical Statistics A. Dasgupta : Asymptotic Theory of Statistics and Probability I.A. Ibragimov, R. Z. Has'minskii : Statistical Estimation : Asymptotic Theory A. W. Van der Vaart : Asymptotics Statistics Jana Jureckova, Pranab Sen, Jan Picek : Methodology in Robust and Nonparametric Statistics Peter J. Huber, Elvezio M. Ronchetti : Robust Statistics Thorsten Dickhaus : Simultaneous Statistical Inference

Semester	**TEN**
Paper	**Major Course - 26**
Paper Code	**STAT1001**
Paper Title	**Special Paper**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1**
	Unit 2
	Unit 3
	Unit 4
Reading/ Reference Lists	

Semester	**TEN**
Paper	**Major Course - 27**
Paper Code	**STAT1002**
Paper Title	**Special Paper**
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1**
	Unit 2
	Unit 3
	Unit 4
Reading/	

Reference Lists	

Semester	**TEN**
Paper	**Major Course - 28**
Paper Code	**STAT1003**
Paper Title	**Research Methodology** Nonparametric and Sequential Inference
No. of Credits	**4**
No. of classes	Theory : 4 Practical : 0
Syllabus	**Unit 1** Empirical distribution function, Glivenko-Cantelli theorem, DKW inequality, VC theory, empirical likelihood, regular statistical functional, U-statistics, strong, weak consistency and limit theorem of U-statistics, degeneracy, V-statistics, plug-in estimators and nonparametric delta method, R-estimators, linear rank statistics and rank limit theorems.
	Unit 2 Tests of location and symmetry : one-sample and two-sample problems, Two-sample scale problem, bivariate sign test, test of randomness, one-sample and two-sample KS test, Cramer von-Mises test.
	Unit 3 Concept of sequential procedures, Wald's fundamental and generalized identity, random walk procedure.
	Unit 4 Concept of OC and ASN, SPRT and its properties, optimality of SPRT (under usual approximation), sequential estimation.
Reading/ Reference Lists	Hajek, J. & Sidek, Z. : Theory of Rank Tests Randles, R. H. & Wolfe, D. A. : Introduction to the theory of nonparametric statistics Hettmansperger, T. P. : Statistical Inference based on ranks Lehmann, E. L. : Theory of Point Estimation Shao, J. : Mathematical Statistics Fraser, D. A. S. : Nonparametric methods in Statistics Gibbons, J. D. : Nonparametric Inference Wald, A. : Sequential Analysis Mukhopadhyay, N. & de Silva, B. M. : Sequential Methods and their applications Gobindarajalu : Sequential Statistics

Semester	**SEVEN**
Paper	**Practical/Sessional Course - 9**
Paper Code	**STAT0791**
Paper Title	**Regression I**
No. of Credits	**4**

No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** General objectives of model building: inference and prediction, difference between parametric and non-parametric approaches. Review of simple linear regression and its properties (including sampling distributions), confidence interval for mean and prediction interval.
	Unit 2 Extension of linear regression: polynomial regression, multiple regression and general linear model, inference in linear model: general linear hypothesis and confidence intervals.
	Unit 3 Regression Diagnostics : Outlier detection, checking for heteroscedasticity and autocorrelation, multicollinearity, tests for normality of errors.
	Unit 4 Linear Smoothers and Non-parametric Regression Techniques: K-NN, Kernel Regression, Splines, Additive models.
Reading/ Reference Lists	Kutner, Nachtsheim, Neter: Applied Linear Regression Models Faraway, J.J.: Linear Models with R Berk, R.A.: Regression Analysis: A Constructive Critique James G,Witten D,Hastie T,Tibshirani R: Introduction to Statistical Learning with Applications in R Hastie,T, Tibshirani R.,Friedman J: Elements of Statistical Learning. Draper,N.R. and Smith,H.:Applied_Regression Analysis. Johnston,J. and DiNardo,J.: Econometric Methods Weisberg, S. :Applied linear regression. Györfi, László, et. al.: A Distribution-Free Theory of Nonparametric Regression. Simonoff, Jeffrey S. : Smoothing Methods in Statistics.

Semester	**SEVEN**
Paper	**Practical/Sessional Course - 10**
Paper Code	**STAT0792**
Paper Title	**Statistical Computing**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** Review of basic data structures, basic plotting techniques and writing functions in R. Basic Statistical methodologies in R. Reading and writing non-R formats, Handling Text and Image data in R, Importing data from the Web, Selective access to data, applying the same function to all parts of a data object. Transforming the data, merging dataframes, reshaping dataframes from wide to long or long to wide. Advanced plotting using ggplot.Generation of reports using Latex: Suggested Editors – Lyx/ Kile/ Texnic-center. Use of R package Knitr/ Markdown to produce reports, Case study using any inbuilt or external dataset to understand and apply the statistical techniques discussed in R and prepare a report.
	Unit 2 Split-apply-combine technique in R, Use of plyr functions. Basic concepts of relational databases; how a database is like an R dataframe. The client/server model. The

	structured query language (SQL) and queries; SELECT and JOIN. R/SQL translations. Accessing databases through R. Introduction to Parallel computing in R.
	Unit 3 Review of concept of Simulation, Different methods of generation of random samples, Monte-Carlo techniques and applications. Mixture models and EM algorithm. Handling missing data.
	Unit 4 Simple optimization: Basics from calculus about minima, Taylor series. Gradient descent and Newton's method. Curve-fitting by optimization. Illustrations with optim and nls. Nelder-Mead and coordinate descent method with applications. Optimization under constraints, using Lagrange multipliers to turn constrained problems into unconstrained ones, Barrier methods for inequality constraints, The correspondence between constrained and penalized optimization, Statistical uses of penalized optimization in regression, Karush–Kuhn–Tucker conditions (concepts only). Stochastic optimization: stochastic gradient descent.
Reading/ Reference Lists	Teetor, P.: The R Cookbook. Chang, W.: The R Graphics Cookbook Spector, P: Data Manipulation with R. Burns, P.: The R Inferno. Matloff, N.: The Art of R Programming: A Tour of Statistical Software Design Ross, S. : Simulation Grolemund, G. and Wickham, H.: R for Data Science. Vandenberghe, L. and Boyd, S.P. : Convex Optimization. Rubin D. and Little, R.J.A. : Statistical Analysis with Missing Data. Xie, Y.: Dynamic Documents with R and knitr

Semester	**EIGHT**
Paper	**Practical/Sessional Course - 11**
Paper Code	**STAT0891**
Paper Title	**Regression II**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** Generalized linear models: Components of a GLM, Goodness of fit – deviance, Residuals, Maximum likelihood estimation. Binary data and Count data: ungrouped and grouped. Polytomous data Overdispersion, Quasi-likelihood. Models with constant coefficient of variation, joint modeling of mean and variance.
	Unit 2 Supervised learning and its decision theoretic formulation, Regression as a supervised learning method, in sample error, and extra sample error, different approaches of model selection : Adjusted R2, AIC, Mallow's Cp, Splitting the dataset, Cross-validation. Bias and Variance Tradeoff.
	Unit 3 High dimensional Regression techniques: Variable selection methods : Best Subset selection, Forward Selection, Backward selection. Shrinkage methods : Ridge Regression,

	Lasso and generalizations. Methods of derived input : Principal Component Regression and Partial Least Squares.
	Unit 4 Regression tree.
Reading/ Reference Lists	McCullagh, P and Nelder, A.J. : Generalized Linear Models. James G, Witten D, Hastie T,Tibshirani R : Introduction to Statistical Learning with Applications in R Hastie,T, Tibshirani R., Friedman J: Elements of Statistical Learning. Faraway, J.J.: Extending the Linear Model with R Breiman, Leo et. al. : Classification and Regression Trees. Agresti, A.: Categorical Data Analysis.

Semester	**EIGHT**
Paper	**Practical/Sessional Course - 12**
Paper Code	**STAT0892**
Paper Title	**Sample Survey and Design of Experiments**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** Probability sampling from a finite population – notions of sampling design, sampling scheme, inclusion probabilities, Horvitz-Thompson estimator of a population total, basic sampling schemes, unequal probability sampling with and without replacement, systematic sampling,related estimators of population total/mean, their variances and variance estimators – mean per distinct unit in simple random with replacement sampling. Hansen-Hurwitz estimator in unequal probability sampling with replacement. Des Raj and Murthy's estimator (for sample of size two) in unequal probability sampling without replacement, unbiased ratio estimators – probability proportional to aggregate size sampling, Hartley-Ross estimator in simple random sampling.
	Unit 2 Sampling and sub-sampling of clusters. Two-stage sampling with unequal number of second stage units and simple random sampling without replacement/unequal probability sampling with replacement at first stage, ratio estimation in two-stage sampling. Double sampling for stratification. Double sampling ratio and regression estimators. Sampling on successive occasions. Introduction to small area estimation.
	Unit 3 Block designs : connectedness, orthogonality, variance balance, construction of mutually orthogonal latin squares (MOLS).
	Unit 4 BIB designs – properties, Intra-block analysis, construction through mols, Bose's difference method and block section and intersection, resolvable BIB designs, factorial designs : analysis, confounding and balancing in symmetric factorials (prime-power case). Brief idea of response surface methodology.
Reading/	Cochran, W. G. : Sampling Techniques (1977)

Reference Lists	Raj, D. & Chandhok, P. : Sample Survey Theory Murthy, M. N. : Sampling : Theory and Methods (1968) Chaudhuri, A. : Modern Survey Sampling (2014) Chaudhuri, A. : Randomized Response and Indirect Questioning in Surveys (2011) Chakraborty, M. C. : Mathematics of Design and Analysis of Experiments Dey, A. : Theory of Block Designs Raghavarao, D. : Constructions & Combinatorial Problems in Designs of Experiments Bose, R. C. : Mathematical Theory of Symmetric Factorial Design (Sankhya – Vol. 8) Bose, R. C. : On the Construction of Balanced Incomplete Block Design (Annals of Eugenics – Vol. 9) Bose, R. C. : On Application of Galois fields to the problem of construction of hyper-graeco-latin square -Sankhya Vol.3, page 328 – 338 Montogomery, D. C. : Design and Analysis of Experiments

Semester	**NINE**
Paper	**Practical/Sessional Course - 13**
Paper Code	**STAT0991**
Paper Title	**Analysis of Time Series and Spatial Data**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** Illustration and recap of time series data and summary statistics like trend, seasonal index, classical decomposition, correlogram. Weakly and strongly stationary stochastic process on time and their interrelationships, Gaussian process on time. WN, MA, AR and ARMA process, existence and uniqueness of stationary solution, causality, invertibility, solution of recurrence relation for finding their ACVF and ACF.
	Unit 2 Estimation in MA, AR and ARMA model, Yule-Walker, MOM and conditional least squares approach, PACF and order selection of MA, AR and ARMA process. Forecasting – Simple Exponential Smoothing, Holt's and Holt-Winters' method. Box-Jenkins approach, ARIMA models. Projection approach for optimal prediction/forecast. Forecast interval and density forecasting. Unit root test for detection of stationarity.
	Unit 3 Frequency domain analysis, Bochner's theorem, Herglotz's theorem, spectral distribution and density of different processes. Estimation in frequency domain, periodogram analysis, inconsistency of periodogram estimator and its remedy using smoothing window estimators.
	Unit 4 Introduction to spatial data – some examples, classifications. Graphical display and summary statistics associated with point-referenced, lattice and spatial point process data, variogram analysis. Modeling of point-referenced sptial data and different methods of kriging.
Reading/ Reference Lists	C.Chatfield : The Analysis of Time Series – An Introduction Brockwell, Peter J. & Davis, Richard A. : Time Series - Theory and Methods G.E.P.Box ,G.M.Jenkins & G.C.Reinsel : Time Series Analysis – Forecasting and Control A.Pankratz : Forecasting with Univariate Box-Jenkins Model G. Jancek and L. Swift : Time Series – Forecasting, Simulation, Applications

	Robert H. Shumway & David S. Stoffer : Time Series Analysis and Its Applications B Ripley : Spatial Statistics N. Cressie : Statistics for Spatial Data N. Cressie & C. Wikle : Statistics for Spatio-temporal Data Sudipto Banerjee, B. P. Carlin & A. E. Gelfand : Hierarchical Modeling and Analysis for Spatial Data

Semester	**NINE**
Paper	**Practical/Sessional Course - 14**
Paper Code	**STAT0992**
Paper Title	**Applied Multivariate Analysis and Resampling**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1** Introduction to multivariate data and potential applications. Curse of dimensionality and need for dimension reduction. Population and sample principal component and their uses. Canonical variables and canonical correlations and their interpretations. The orthogonal factor model, estimation of factor loading and factor scores. Multidimensional scaling. MANOVA.
	Unit 2 Difference between supervised and unsupervised learning. Hierarchical clustering for continuous and categorical variables, use of different proximity measures, non-hierarchical clustering methods : k-means clustering and related methods.
	Unit 3 Classification and discrimination procedures for discrimination between populations, classification using linear and logistic regression and nearest neighbor approach. Decision theoretic formulation: Bayes, minimax and likelihood ratio procedures, discrimination between two multivariate normal populations and linear discriminant analysis. Fisher's LDF. Classification tree.
	Unit 4 Introduction to the Jackknife, bias reduction using Jackknife, Jackknife bias estimate of standard statistics, Tukey's Jackknife variance estimate, introduction to deleted jackknife. Introduction to the bootstrap method, bootstrap sampling distribution of a statistic, bootstrap in regression models, bootstrap consistency measures.
Reading/ Reference Lists	R. A. Johnson & D. W. Wichern : Applied Multivariate Statistical Analysis. Léopold Simar & Wolfgang Härdle : Applied Multivariate Statistical Analysis. K. V. Mardia, J. T. Kent, J. M. Bibby : Multivariate Analysis T.W. Anderson : An Introduction to Multivariate Analysis. G.A.F. Seber : Multivariate Observations. B.Efron : The Jackknife, the Bootstrap and other Sampling Plans B.Efron : Bootstrap methods – another look at jackknife B.Efron & R.J.Tibshirani : An Introduction to the Bootstrap A. C. Davison & D. V. Hinkley : Bootstrap Methods and Their Application

Semester	**TEN**
Paper	**Practical/Sessional Course - 15**
Paper Code	**STAT1091**
Paper Title	**Combined Lab for STAT1001, STAT1002 and STAT1003**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1**
	Unit 2
	Unit 3
	Unit 4
Reading/ Reference Lists	

Semester	**TEN**
Paper	**Practical/Sessional Course - 16**
Paper Code	**STAT1092**
Paper Title	**Project**
No. of Credits	**4**
No. of classes	Theory : 2 Practical : 4
Syllabus	**Unit 1**
	Unit 2
	Unit 3
	Unit 4
Reading/ Reference Lists	