"Education for Knowledge, Science and Culture"

-Shikshanmaharshi Dr.Bapuji Salunkhe

Shri Swami Vivekanand Shikshan Sanstha's

VIVEKANAND COLLEGE (AUTONOMOUS), KOLHAPUR

Department of Statistics

M. Sc. I

Semester I & II

CBCS syllabus to be implemented from June 2022 Onwards

Shri Swami Vivekanand Shikshan Sanstha

Vivekanand College Kolhapur (Autonomous)

Department of Statistics

M. Sc. Part I-Statistics

Semester I & II

Syllabus to be implemented from
Academic year 2022-23

Objectives:

1.The students are expected to understand the principles, concepts, and recent developments in the Statistics.

2. To enhance student sense of enthusiasm for Statistics and to involve them in an intellectually stimulating experience of learning in a supportive environment.

3. The practical course is framed in relevance with the theory courses to improve the understanding of the various concepts in Statistics.

Program Outcomes (PO):

On successful completion of the program students will able to:

PO1: Understand the principles and concepts in the statistical theory at an advanced level which take into account recent advances in the subject.

PO2: Acquire the strong foundation of statistical concepts which will benefit them to become good Statistician.

PO3: Use acquired statistical methodologies and modelling techniques to address real-life problems.

PO4: Gain the knowledge of software which has the wide range of opportunities in the Quality control, Planning and development, IT sector, industries, Business, Government and private sector etc.

PO5: Qualify various National / State level competitive exams like ISS, DSO, CSIR-UGC NET, SET, GATE, MPSC, UPSC, Banking etc.

Program Specific Outcomes (PSO):

On successful completion of the program students will able to:

PSO1: Enhance sense of enthusiasm for Statistics and to involve them in an intellectually stimulating experience of learning in a supportive environment.

PSO2: Handle and analyse small as well as large databases with computer skills.

PSO3: Understand, implement and develop statistical models.

PSO4: Describe complex statistical ideas to non-statisticians and to present the results of their analyses in written, oral forms and can make practical suggestions for improvement.

PSO5: Apply statistical techniques to optimize and monitor real life phenomena related to industry and business analytics etc.

FEATURES OF DEPARTMENT:

1) **Library:**

Reference and Textbooks, Journals and Periodicals,

2) **Equipment's in Laboratory:**

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

3) Laboratory Software's:

1) R Software 2) Python

1. **Title:** M. Sc. (Statistics)

2. **Year of Implementation:** The syllabus will be implemented from June, 2022-23 onwards.

3. **Duration:** Two Years

4. **Pattern:** M. Sc. Statistics program has semester pattern and Choice Based Credit System. The program consists of 96 credits.

5. **Medium of instruction:** English

6. Structure of course:

1	CC	Core Course
2	CCS	Core Course Specialization
3	CCPR	Core Course Practical
4	DSE	Discipline Specific Elective

Course	No. of course	Credit per Course	Total Credit	% of Credit
CC	14	4	56	58.33
CCS	4	4	16	16.67
DSE CCPR	2	4	8	8.33
	4	4	16	16.67
	24		96	100

M.Sc. (Statistics) Semester – I

Course Code	Title of the course	Instruction Hrs/week	Marks- End Semester Exam	Marks- Internal Assessment	Credits
CC-2300A	Real Analysis	4	80	20	4
CC-2301A	Linear Algebra	4	80	20	4
CC-2302A	Distribution Theory	4	80	20	4
CC-2303A	Estimation Theory	4	80	20	4
CC-2304A	Statistical Computing	4	80	20	4
CCPR-2305A	Practical-I	12	100	--	4
Total Credits of Sem-I					**24**

M.Sc. (Statistics) Semester – II

Course Code	Title of the course	Instruction Hrs./week	Marks- End Semester Exam	Marks- Internal Assessment	Credits
CC-2306B	Probability Theory	4	80	20	4
CC-2307B	Theory of Testing of Hypotheses	4	80	20	4
CC-2308B	Linear Models and Regression analysis	4	80	20	4
CC-2309B	Design and analysis of Experiment	4	80	20	4
CC-2310B	Sampling Theory & Official Statistics	4	80	20	4
CCPR-2311B	Practical-II	12	100	--	4
Total Credits of Sem-II					**24**

Syllabus:
Semester I:

CC-2300A: REAL ANALYSIS

Course Objectives: At the end of the course students will be able to:

CO1: Define and recognize the basic properties of the field of real numbers.

CO2: Define and recognize the series of real numbers and convergence.

CO3: Apply the theorem in a correct mathematical way.

CO4: Define and recognize the real functions and its limits and differentiability of real functions and its related theorems.

Unit and Credit	CC-2300A: REAL ANALYSIS	No. of hoursper unit / credits
Unit I	Set of real numbers, countable and uncountable sets, countability of rational numbers and uncountability of the interval (0,1) Supremum and Infimum of bounded sets, limit point of a set, open, closed, dense and compact sets. Bolzano-Weierstrass and Heine-Borel Theorems (Statements only). Applications of the theorems	15
Unit II	Sequence of real numbers, convergence, divergence, Cauchy sequence, Convergence of bounded monotone sequence. Limit inferior and limit superior of the sequences. Series of numbers, testsfor convergence (without proof) test for absolute convergence, convergence of sequences of non-negative terms.	15
Unit III	Real valued function, continuous function, Uniform continuity of sequence of functions,Uniform convergence of series of functions with special emphasis on power series, radius of convergence. Riemann, Riemann -Steltjes Integrals and their common properties. Integration by parts, Fundamental theorem on calculus, mean value theorem, their applications in finding functional of distributions.	15
Unit IV	Vector and Matrix differentiation, Maxima, minima of functions of several variables. Constrained maxima, minima, Lagrange's method, Taylor's theorem (without proof), implicit function theorem and their applications. Multiple integrals, Change of variables, Improper integrals, Applications in multivariate distributions. Theorem on differentiation under integral sign (without proof), Leibnitz rule (statement only) and applications.	15

Books Recommended:

1. S. C. Malik & S. Arora (1991): Mathematical Analysis, Wiley Eastern Limited-IInd edition.
2. R. R. Goldberg (1964): Methods of Real Analysis, Blais dell Publishing company, Newyork,

U.S.A.

3. G.R. Bartle (1976): Element of Real Analysis, Wiley, 2nd edition, 1976.
4. G.R. Bartle & D. R. Sherbert (2000): Introduction to Real Analysis-John, Wiley & Son Inc, 2000.
5. Royden(1988): Principles of Real Analysis, Mac million.
6. Widder(1989): Advanced Calculus, Dover Publication, 1989.
7. Apostol (1985): Mathematical Analysis, Narosa Publishing House, T. M., 1985.

CC-2301A: LINEAR ALGEBRA

Course Objectives: At the end of the course students will be able to:
CO1: Solve matrix operations, including inverses and determinants.

CO2: Demonstrate understanding of the concepts of vector space and subspace, linear independence, span, and basis.

CO3: Describe eigenvalues and eigenvectors and solve eigenvalue problems.

CO4: Apply principles of matrix algebra to linear transformations and solve systems of linear equations using multiple methods.

Unit and Credit	CC-2301A: LINEAR ALGEBRA	No. of hoursper unit / credits
Unit I	Vector space, subspace, linear dependence and independence, basis, dimension of a vector space, example of vector spaces. Null space, Gram- Schmidt orthogonalization process, Orthonormal basis, orthogonal projection of a vector, Linear transformations, algebra of matrices, row and column spaces of a matrix, elementary operations and elementary matrices, rank and inverse of a matrix, Null space and nullity, partitioned matrices	15
Unit II	Permutation matrix, reducible/ irreducible matrix, primitive / imprimitive matrix, idempotent matrix, Kronecker product, Generalized inverse, Moore-Penrose generalized inverse, Solution of a system of homogenous and non-homogenous linear equations, theorem related to existence of solution and examples.	15
Unit III	Characteristic roots and vectors of a matrix, algebraic and geometric multiplicities of a characteristic root, right and left characteristic vectors, orthogonal property of characteristic vectors, Caley-Hamilton Theorem and its applications.	15
Unit IV	Spectral decomposition of a real symmetric matrix, singular value decomposition, Choleskey decomposition, real quadratic forms, reduction and classification, index and signature, extreme of a quadratic form, simultaneous reduction of two quadratic forms.	15

Books Recommended:

1. F.A. Graybill, An Introduction to Linear Statistical Models Vol 1, Mc Graw-Hill Book Company Inc,1961.
2. G. Hadely, Linear Algebra, Narosa Publishing House, 1962.
3. D. Harville, Matrix Algebra from Statistics Perspective, Springer, 1997.
4. A. R. Rao and P. Bhimasankaram, Linear Algebra, Hindustan Book Agency, Second dition, 2000.
5. C. R. Rao, Linear Statistical Inference and Its Applications, Wiley, Second Edition, 2001.
6. J. Schott, Matrix Analysis for Statistics, Wiley, Third edition, 2016.
7. S. B. Searl, Matrix Algebra Useful for Statistics, Wiley, 2006.
8. Kshirsagar A.M (1983): Course in linear Models-Marcel Dekker.

CC-2302A: DISTRIBUTION THEORY

Course Objectives: At the end of the course students will be able to:

CO1: Recognize and learn concept of mixture of distribution and their decomposition.

CO2: Execute transformation of univariate random variables and different moment inequalities.

CO3: Describe the concept of central and non-central distributions.

CO4: Learn the concept of order statistics.

Unit and Credit	CC-2302A: DISTRIBUTION THEORY	No. of hours per unit / credits
Unit I	Review of Random experiment and its sample space, events, random variables, discrete random variables, continuous random variables. Cumulative distribution function (CDF), properties of CDF, computation of probabilities of events using CDF, quantiles, absolutely continuous and discrete distributions, mixtures of probability distributions, decomposition of mixture CDF into discrete and continuous CDFs, expectation and variance of mixture distributions.	15
Unit II	Transformations of univariate random variables, probability integral transformation. Concepts of location, scale and shape parameters of distributions with examples. Symmetric distributions and their properties. Moment inequalities (with proof): Basic, Holder, Markov, Minkowski, Jensen, Tchebysheff and their applications	15
Unit III	Random vectors, joint distributions, Independence, variance-covariance matrix, joint MGF. Conditional expectation and variances, Transformations of bivariate random variables, Bivariate Normal distribution, Marshall-Olkin bivariate exponential distribution, Bivariate Poisson distribution. Convolutions, compound distributions.	15

Unit IV	Sampling distributions of statistics from univariate normal random samples: central and non-central chi-square, t and F distributions. Distributions of linear and quadratic forms involving normal random variables, Fisher Cochran and related theorems: statement and applications. Order Statistics: Distribution of an order statistics, joint distributions of two order statistics, distribution of spacings, normalized spacings with illustration to exponential case, distribution of sample median and sample range.	15

Books Recommended:

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

CC-2303A: ESTIMATION THEORY

Course Objectives: At the end of the course students will be able to:

CO1: Describe the notion of a parametric models, point estimation of the parameters of those models.

CO2: Construct the sufficient statistic, minimal sufficient statistic, m.l.e., moment estimator of the parameter.

CO3: Discuss the concept of MVUE, MVBUE, UMVUE.

CO4: Describe the concept of Bayesian inference and their real life applications.

Unit and Credit	**CC-2303A: ESTIMATION THEORY**	**No. of hoursper unit / credits**
Unit I	Sufficiency principle, factorization theorem, minimal sufficiency, minimal sufficient partition, construction of minimal sufficient statistics, minimal sufficient statistic for exponential family, power series family, curved exponential family, Pitman family. Completeness, bounded completeness, ancillary statistics, Basu's theorem and applications.	15
Unit II	Problem of point estimation, unbiased estimators, minimum variance unbiased estimator, Rao- Blackwell theorem and Lehmann-Scheffe theorem and their uses. Necessary and sufficient condition for MVUE and their applications. Fisher information and information matrix, Cramer- Rao inequality, Chapmann-Robinson bounds, Bhattacharya bounds, their applications.	15
Unit III	Method of maximum likelihood (MLE) and small sample	15

	properties of MLE, method of scoring and application to estimation in multinomial distribution. MLE in non-regular families. Other methods of estimation: method of moments, minimum Chi square. U-Statistics: one and two sample; U-Statistics theorem for one sample and two sample (statements only).	
Unit IV	The concept of prior distributions, various types of priors, non-informative, Jeffrey's, least favorable prior, posterior distribution; Posterior distribution conjugate family and standard examples of such families. Bayes estimation under squared error and absolute error loss functions.	15

Books Recommended:

1. V. K. Rohatgi, and A. K. MD. E. Saleh (2015): Introduction to Probability Theory and MathematicalStatistics, John Wiley & sons, 3rd Edition.
2. E. L. Lehmann (1983): Theory of Point Estimation, John Wiley & sons.
3. C. R. Rao (1973): Linear Statistical Inference and its Applications, wiley, 2nd Edition.
4. B. K. Kale, and K. Muralidharan (2015): Parametric Inference: An Introduction, Alpha Science InternationalLtd.
5. P. Mukhopadhyay (2015): Mathematical Statistics, Books and Allied (p)Ltd.
6. E. J. Dudewicz and S. N. Mishra (1988): Modern Mathematical Statistics, John Wiley and Sons.
7. Casella and Berger (2002): Statistical Inference, Duxbury advanced series, IInd edition.

CC-2304A: STATISTICAL COMPUTING

Course Objectives: At the end of the course students will be able to:

CO1: Construct formulas, including the use of built-in functions and analysis tool pack.

CO2: Develop the fundamentals of statistical analysis in R environment.

CO3: Describe the simulation involves building mathematical models that attempt to duplicate real-world systems or problems

CO4: Implement different resampling technique in real situations.

Unit and Credit	CC-2304A: STATISTICAL COMPUTING	No. of hoursper unit / credits
Unit I	MSEXCEL: Introduction to MSEXCEL. Cell formatting, conditional formatting, Data manipulation using EXCEL: sort and filter, find and replace, text to columns, remove duplicate, data validation, consolidate, what-if-analysis. Working with Multiple Worksheets and Workbooks. Built-in mathematical and statistical functions for obtaining	15

	descriptive statistic, computing PMF/PDF, CDF and quantiles of the well known distributions, rand and randbetween function, Logical functions: if, and, or, not. Lookup functions: hlookup, vlookup, Formula Errors, Creating and Working with Charts, Database functions, Text functions, Date and time functions, Excel add-ins: analysis tool pack, Pivot tables and charts.	
Unit II	R-software: Introduction to R, data types and objects, operators, data input, data import and export, built in functions for descriptive statistics, random sampling and computation of pdf, cdf and quantiles of well known distribution. Strings and Dates in R. apply family of functions. Saving work in R. Matrix algebra, graphical procedures, frequencies and cross tabulation, built in functions: lm, t.test, prop.test, wilcox.test, ks.test, var.test, chisq.test, aov. Control statements. Programming, user defined functions, Rpackages. R-studio.	15
Unit III	Concept of simulation. Concept of random number generator, true random number and pseudo random number generators, requisites of a good random number generator. Tests for randomness. Congruential method of generating uniform random numbers. Algorithms for generating random numbers from well known univariate discrete and continuous distributions, generating random vectors from multinomial, bivariate normal, and bivariate exponential distributions, generating random numbers from mixture of distributions (related results without proofs). Acceptance-Rejection Technique. Use of random numbers to evaluate integrals, to study the systems involving random variables, to estimate event probabilities and to find expected value of random variables. Use of random numbers in statistical inference.	15
Unit IV	Resampling techniques: Bootstrap methods, estimation of bias and standard errors,estimation of sampling distribution, confidence intervals. Jackknife method: estimation of bias and standard errors, bias reduction method. Solution to system of linear equations: Jacobi and Gauss-Seidel methods with convergence analysis. Finding roots of nonlinear equation: Newton-Raphson method, bisection method; Newton-Raphson for system of nonlinear equations. Numerical integration: quadrature formula, trapezoidal rule and Simpson's rules for single integral.	15

Books Recommended:

1.Atkinson K. E. (1989): An Introduction to Numerical Analysis. (Wiley)
2. Devroye L. (1986): Non- Uniform Random Variate Generation. (Springer- Verlag New York)

3. Efron B. and Tibshirani. R. J. (1994): An Introduction to the Bootstrap. (Chapman and Hall)
4. Morgan B. J. T. (1984): Elements of Simulation. (Chapman and Hall)
5. Robert C. P. and Casella G. (1999): Monte carlo Statistical Methods. (Springer-verlag New York, Inc.)
6. Ross. S. M. (2006): Simulation. (Academic Press Inc)
7. Rubinstein, R. Y. (1998): Modern Simulation and Modeling. (Wiley Series in Probability and Statistics)
8. William J., Kennedy, James E. Gentle. (1980): Statistical Computing. (Marcel Dekker)

CCPR-2305A: PRACTICAL -I

Practical Number	Practical Name
1	Linear dependence and Independence of vectors and rank of matrix
2	Gram-Schmidt orthogonalization method
3	Solving system of linear equations
4	Computation of Inverse and G-inverse of a matrix.
5	Applications of Cayley-Hamilton theorem.
6	Inverse of partioned matrix.
7	Characteristics roots and vectors and their applications.
8	Classifications and reduction of quadratic forms.
9	Sketching of pdf and CDF for Discrete distribution
10	Sketching of pdf and CDF for Continuous distribution
11	Sufficient, minimal sufficient, and complete sufficient statistics
12	UMVUE and lower bunds for variances of unbiased estimators
13	Maximum likelihood and method of moments estimation
14	Method of Scoring and method of minimum chi-square estimation
15	Practical on MSEXCEL
16	Practical on R- Software
17	Random Number Generation from Discrete and Continuous distribution
18	Applications of Simulation
19	Numerical Methods and Resampling Techniques

(Each practical should consist of problems to be solved using at least two of the following software: EXCEL/ R/python)

Semester II:

CC-2306B: PROBABILITY THEORY

Course Objectives: At the end of the course students will be able to:

CO1: Memorize the basic concepts of Sets, Sequence, Measurable function and limit.

CO2: Recognize the measure theory, random variable, distribution function, limit of sequence variables.

CO3: Explain the concept of convergence and applications with example.

CO4: Implement the central limit theorem and large-sample approximations for common statistics

Unit and Credit	**CC-2306B: PROBABILITY THEORY**	**No. of hoursper unit / credits**
Unit I	Classes of sets: Sequence of sets: limsup, liminf and limit of sequence of sets field, σ- field, σ- field generated by a class of sets, Borel σ- field. Probability measure, Probability space, properties of a probability measure, continuity, mixture of probability measures. Lebesgue and Lebesgue-Steltjes measures on R. Independence of events.	15
Unit II	Measurable function, random variable, distribution function of a random variable, simple random variable, elementary random variable, liminf, limsup and limit of sequence of random variables. Method of obtaining a random variable as a limit of sequence of simple random variables. Integration of a measurable function with respect to a measure, expectation of a random variable, independence. Characteristic function, simple properties. Inversion theorem and uniqueness property (Statement only).	15
Unit III	Monotone convergence theorem, Fatous Lemma, Dominated Convergence theorem, Borel- Cantelli Lemma, (Statements only), and their applications. Convergence of sequence of random variables, Convergence in distribution, Almost sure convergence, a characterizing property, convergence in probability, uniqueness of limit, Yule Slutsky results and preservation under continuous transform. Convergence in r^{th} mean, interrelationships (Statements only), their illustration with examples	15
Unit IV	Weak and Strong laws of large numbers, Kolmogorov's three series theorem for almost sure convergence (Statement only), Liaponove's, Lindeberg- Feller Theorems on CLT (Statement only). Applications of the above results. b) Moment inequalities: - Markov, Chebychev, Holder, Minkowski and Jensen inequalities with their applications.	15

	Basic inequality Liapunov's.	

Books Recommended:

1. Bhat B. R. (1981): Modern Probability Theory –IIIrd edition: New age international limited.
2. Alan Karr, (1993) : Probability Theory – Springer Verlag.
3. Billingsley P. (1986): Probability & Measure –John Wiley and sons
4. Athreya K. B. and Lahiri S. (2006). Probability Theory, (Hindustan Book Agency).
5. Feller, W. (1969). Introduction to Probability and its Applications vol.II (Wiley Eastern Ltd.)
6. Loeve, M. (1978). Probability Theory (Springer Verlag). Fourth edition
7. Rohatgi, V.K. and Saleh, A. K. MD. E. (2015). Introduction to Probability Theory andMathematical Statistics -3rd Edition, John Wiley & sons.

CC-2307B: THEORY OF TESTING OF HYPOTHESIS

Course Objectives: At the end of the course students will be able to:

CO1: Formulate null and alternative hypotheses, compute probabilities of types of error, MP tests and MLR property.

CO2: Understand UMP and UMPU test with their applications.

CO3: Construct asymptotic confidence interval of a parameter and its relation with testing of hypothesis problem.

CO4: Execute small, large sample size tests and non-parametric tests in real life problems.

Unit and Credit	**CC-2307B: THEORY OF TESTING OF HYPOTHESIS**	**No. of hours per unit / credits**
Unit I	Problem of testing of Hypothesis, Simple and composite hypotheses. Randomized and non- randomized tests, Most powerful test, Neyman-Pearson Lemma and its applications. Determination of minimum sample size to achieve the desired strengths.Monotone likelihood ratio property, UMP test, power function of a test, existence of UMP.Tests for one-sided alternatives.Concept of p- value.	15
Unit II	UMP tests for two sided alternatives examples, their existence and non- existence. Generalized Neyman Pearson lemma, unbiased test, UMPU test and their existence in the case of exponential families (Statements of the theorems only). Similar tests, test with Neyman structure.	15
Unit III	Problem of confidence intervals, relation with testing of hypotheses problem, shortest length confidence intervals, UMA and UMAU confidence intervals.	15
Unit IV	Likelihood ratio test and its application to standard distribution. Goodness of fit tests based on Chi-square distribution and application to contingency tables. Spearman's Rank Correlation Test; Kendall's Rank	15

	Correlation Test; Kruskal-Wallis Test; Fridman's Two-way analysis of variance by ranks.	

Books Recommended:

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

CC-2308B: Linear Models and Regression Analysis.

CO1: Understand General linear model, Gauss Markov theorem, variances and covariance's of BLUEs.
CO2: Understand and apply multiple regression models in real life situations.
CO3: Understand concept of multicollinearity and non-linear regression.
CO4: Understand concept of Robust regression.

Unit and Credit	**CC-2308B: Linear Models and Regression Analysis.**	**No. of hours per unit / credits**
Unit I	General linear model: definition, assumptions, concept of estimability, least squares estimation, BLUE, estimation space, error space, Guass Markov theorem, variances and covariances of BLUEs, Distribution of quadratic forms for normal variables: related theorems (without proof), Tests of hypotheses in general linear models. Description of the ANOVA and linear regression models as the particular cases of the general linear model.	15
Unit II	Multiple regression model, Least squares estimate (LSE), Properties of LSE, Hypothesis testing, confidence and prediction intervals, General linear hypothesis testing. Dummy variables and their use in regression analysis. Model adequacy checking. Transformations to correct model inadequacies: VST and Box-Cox power transformation.	15

Unit III	Multicollinearity: Consequences, detection and remedies, ridge regression. Autocorrelation: sources, consequences, detection (Durbin-Watson test) and remedies. Parameter estimation using Cochrane-Orcutt method. Variable Selection Procedures: Rsquare, adjusted R-square, Mallows' Cp, forward, backward and stepwise selection methods, AIC, BIC.	15
Unit IV	Robust Regression: need for robust regression, M-estimators, properties of robust estimators: breakdown and efficiency. Asymptotic distribution of M-estimator (Statement only). Nonlinear Regression Models: nonlinear least squares, transformation to a linear model, parameter estimation in a nonlinear system, linearization. Polynomial regression model, piecewise polynomial fitting.	15

Books Recommended:

1.Kshirsagar A. M. (1972): Multivariate Analysis. Marcel-Dekker.
2. Johnson, R.A. and Wichern. D.W (2002): Applied multivariate Analysis. 5thAd.Prentice – Hall.
3. Anderson T. W. (1984): An introduction to Multivariate statistical Analysis2nd Ed. John Wiely.
4. Morrison D.F. (1976): Multivariate Statistical Methods McGraw-Hill.

CC-2309B: DESIGN AND ANALYSIS OF EXPERIMENT

Course Objectives: At the end of the course students will be able to:

CO1: Memorize the basic concepts of design of experiments, concept of confounding.

CO2: Analyse different factorial and fractional experiments their interactions, graphical representation and confounding.

CO3: Describe the concept of fractional factorial design.

CO4: Understand the concept of response surface and methods of fitting it.

Unit and Credit	**CC-2309B: DESIGN AND ANALYSIS OF EXPERIMENT**	**No. of hoursper unit / credits**
Unit I	Concept of design of experiments (DOE), applications of DOE; Basic principles of DOE; Analysis of completely randomized design using the fixed effect model and estimation of the model parameters; Contrasts, orthogonal contrasts, Scheffe's method for comparing contrasts; Comparing pairs of treatment means: controlling false discovery rate, Tukey's test, Fisher least significant difference method; Comparing treatment means with a control; Analyses of randomized complete block design, Latin square design, balanced incomplete block design using fixed effect models and estimation of the model parameters.	15

Unit II	Concepts of factorial designs, main effects, and interaction effects; The two-factor factorial design and its analysis using fixed effect model; The general factorial design; Analysis of replicated and unreplicated 2^k full factorial designs; Blocking and confounding in a 2^k factorial design; Construction and analysis of 2^{k-p} fractional factorial designs and their alias structures; Design resolution, resolution III and resolution IV designs; fold over designs; saturated designs.	15
Unit III	The 3^k full factorial design and its analysis using fixed effect model; Confounding in 3^k factorial designs; Construction and analysis of 3^{k-p} fractional factorial designs and their alias structures; Factorials with mixed levels: factors at two and three levels, factors at two and four levels; Design optimality criteria; Concept of random effects and mixed effects models, analysis of 2^k factorial designs using the random effect model, analysis of 2^k factorial designs using the mixed effect model, rules for expected mean squares, approximate F-tests.	15
Unit IV	Response surface methodology: the method of steepest ascent, analysis of the response surface using first and second order model, characterizing the response surface, ridge systems, multiple responses, designs for fitting response surfaces: simplex design, central composite design (CCD), spherical CCD, Box–Behnken design; Robust parameter design: crossed array designs and their analyses, combined array designs and the response model approach; The concepts of nested and split-plot designs.	15

Books Recommended:

1.Montgomery D.C. (2017): *Design and Analysis of Experiments*, 9th edition, John Wiley & Sons, Inc.

2. Phadke, M. S. (1989). *Quality Engineering using Robust Design*, Prentice-Hall.

3. Voss, D., Dean, A., and Dean, A. (1999). *Design and Analysis of Experiments*, Springer verlag Gmbh.

4. Wu, C. F., Hamada M. S. (2000). *Experiments: Planning, Analysis and Parameter Design Optimization, 2nd edition*, John Wiley & Sons.

CC-2310B: SAMPLING THEORY

Course Objectives: At the end of the course students will be able to:

CO1: Understand the basic concept of random sampling and different methods of sampling.

CO2: Apply unequal probability sampling designs viz. PPSWR, PPSWOR including Lahiri's method and Murthy's estimator for survey.

CO3: Implement Cluster sampling, Two –stage sampling, Multistage sampling, Ratio and Regression estimation in real life problems.

CO4: Recognize non-sampling error, Response and non-response errors. Apply different

model andtechnique to overcome errors.

Unit and Credit	CC-2310B: SAMPLING THEORY	No. of hoursper unit / credits
Unit I	Review of concept Simple random sampling with replacement (SRSWR) and Simple random sampling without replacement (SRSWOR), results related to SRSWR and SRSWOR, estimation of sample size. Stratified sampling: Stratification, allocation and estimation problems, comparison with SRS, post stratification, construction of strata, deep stratification, method of collapsed strata, Review of concept of Systematic sampling: linear systematic sampling and circular systematic sampling, Comparison with SRS, and Stratified sampling.	15
Unit II	PPSWR methods: Cumulative total method, Lahiri's method related estimation Problems and PPSWOR methods and related estimation of a finite population mean (Horwitz-Thompson and Des Raj estimators for a general sample size and Murthy's estimator for a sample of size 2, Midzuno sampling, Rao-Hartley-Cochran sampling Strategy.	15
Unit III	Use of supplementary information for estimation: ratio and regression estimators and their properties. Unbiased and almost unbiased ratio type estimators, Double sampling. Cluster sampling. Two–stage sampling with equal number of Second stage units, multistage-sampling. Stratification estimator, Multiphase sampling.	15
Unit IV	Non-sampling errors: Response and non-response errors. Hansen–Hurwitz and Deming's model for the effect of call-backs. Random response techniques, dichotomous population, Warners model, MLE in Warners model, unrelated question model, polychotomous population: use of binary and vector response, binary response and unrelated questions, Multiattribute situations.	15

Books Recommended:

1. Parimal Mukhopadhyay, Theory and methods of survey sampling, Prentice Hall of India private limited,2nd Edition, 2008.
2. P. V. Sukhatme, S. Sukhatme & C Ashok, Sampling Theory of surveys and applications, Iowa universitypress and Indian society of agricultural statistics, New Delhi, 1984.
3. Chaudhuri and H. Stenger, Survey Sampling: Theory and Methods, chapman and hall/CRC, 2nd edition,2005.
4. Des Raj and Chandhok. P., Sample Survey Theory, Nanopublications, 1998.
5. William G. Cochran, Sampling Techniques, John and Wieley sons Inc, IIIrd edition 1977.
6. M. N. Murthy, Sampling Theory of Methods, Statistical Publishing Society, Calcutta, 1977.

7. D. Singh and F. S. Chaudhary, Theory and Analysis of Sample Survey Designs, Wiley Eastern Limited,1986.
8. S. Singh, Advance Sampling Theory and Applications (Volume I and II), Kluwer Academic Publishers,2003.

CCPR-2311B: PRACTICAL -II

Course Objective: Students should to understand and implement theory in real life problems.

Practical Number	Practical Name
1	MP, UMP, and UMPU Tests
2	Likelihood ratio tests
3	Confidence Intervals
4	Non-parametric Tests
5	Linear Estimation: Estimation and Hypothesis testing
6	Multiple linear regression
7	Variable selection, Multicollinearity and Autocorrelation
8	Robust regression and nonlinear regression
9	Analysis of CRD, RBD, LSD
10	Analysis of BIBD
11	Analysis of full, confounded and fractional 2^k factorial designs
12	Analysis of full, confounded and fractional 3k factorial designs
13	Response surface methodology and robust parameter designs
14	Simple random sampling.
15	Stratified, Systematic and cluster Sampling.
16	Ratio, regression method of estimations.
17	Des-Raj, Murthy's and Horvitz-Thompson estimators.
18	Multi-stage sampling
19	Non-sampling errors.

(Each practical should consist of problems to be solved using at least two of the following software: EXCEL/ R/python)

Nature of Theory Question Paper:

Time: 3 hours **Total Marks: (70)**

Instructions: (1) All the questions are compulsory.
(2) Figures to the **right** indicate **full** marks.
(3) (Paper setter may add or delete any instruction if required)

Question Number	**Pattern of Question**	**Marks**
Q.1	Select correct Alternative (8 questions carrying 1 mark each)	1 X 8 =8
Q.2	Attempt any three i) ii) iii) iv) v)	16 X 3 =48
Q.3	Attempt any four i) ii) ii) iv) v) vi)	6 X 4 =24
	Total	**80**

Nature of Practical Question Paper:

a) For Semester I and II, "Practical CCPR-2305, CCPR-2311,

1) There shall be 20 marks for day-to-day performance and journal.
2.) Examination (60): Practical Examinations will be conducted at the end of the term. Practical exam will be of 3 hrs. duration carrying 60 marks. There shall be 8 questions each of 12 marks, of which a student has to attempt any 5 questions.
3) Practical VIVA will be for 20 marks.

b) For Semester III and IV: Practical CCPR-2319, CCPR-2327

1. There shall be 10 marks for day-to-day performance and journal.
2. Examination (50): Practical Examinations will be conducted at the end of the term. Practical exam will be of 3 hrs. duration carrying 50 marks. There shall be 7 questions each of 10 marks, of which a student has attempt any 5 questions.
3. Practical VIVA will be for 10 marks.

4. Project work carries 60 marks.

Semester		Marks	Total Marks
III	Search & Define Problem	10	30
	Data Collection, Variable Understanding	10	
	Exploratory Data Analysis	10	
IV	Data Analysis	10	30
	Project Report	10	
	PPT and VIVA	10	

Note: The Master in Statistics Practical (MSP) examination shall be conducted semester wise with individual heads of passing with minimum 40% marks.

Nature of Internal Assessment:
There shall be Continuous Internal Evaluation pattern as follows:

1	**Attendance**	**5 Marks**
2	**Seminar**	**15 Marks**
3	**Internal exam**	**20 Marks**

Conversion of 40 marks into 20 marks.

VIVEKANAND COLLEGE ESTD JUNE 1964 KOLHAPUR - 416003

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