M.Sc. (Statistics) Programme structure (CBCS PATTERN) (2019-20) M.Sc. Part – I

SEMESTER-I (Duration- Six Month)											
	Sr. No.	Course Code	Teaching Scheme			Examination Scheme					
			Theory and Practical			University Assessment (UA)			Internal Assessment (IA)		
			Lectures (Per week)	Hours (Per week)	Credit	Maximum Marks	Minimum Marks	Exam. Hours	Maximum Marks	Minimu m Marks	Exam. Hours
CGPA	1	CC-101	4	4	4	80	32	3	20	8	1
	2	CC-102	4	4	4	80	32	3	20	8	1
	3	CC-103	4	4	4	80	32	3	20	8	1
	4	CC-104	4	4	4	80	32	3	20	8	1
	5	CC-105	4	4	4	80	32	3	20	8	1
	6	CCPR-106	12	12	4	100	40	*	--	--	--
Total (A)			**--**	**--**	**24**	**500**	**--**	**--**	**100**	**--**	**--**
Non-CGPA	1	AEC-107	2	2	2	--	--	--	50	20	2
SEMESTER-II (Duration- Six Month)											
CGPA	1	CC-201	4	4	4	80	32	3	20	8	1
	2	CC-202	4	4	4	80	32	3	20	8	1
	3	CC-203	4	4	4	80	32	3	20	8	1
	4	CC-204	4	4	4	80	32	3	20	8	1
	5	CC-205	4	4	4	80	32	3	20	8	1
	6	CCPR-206	12	12	4	100	40	*	--	--	--
Total (B)			**--**	**--**	**24**	**500**	**--**	**--**	**100**	**--**	**--**
Non-CGPA	1	SEC-207	2	2	2	--	--	--	50	20	2
Total (A+B)					**48**	**1000**	**--**	**--**	**200**	**--**	**--**

• Student contact hours per week : **32** Hours (Min.)	• Total Marks for M.Sc.-I : **1200**
• Theory and Practical Lectures : **60** Minutes Each	• Total Credits for M.Sc.-I (Semester I & II) : **48**
• CC-Core Course • CCPR-Core Course Practical • AEC-Mandatory Non-CGPA compulsory Ability Enhancement Course • SEC- Mandatory Non-CGPA compulsory Skill Enhancement Course	• Practical Examination is annual. • Examination for CCPR-106 shall be based on Semester I Practical. • Examination for CCPR-206 shall be based on Semester II Practical. • *Duration of Practical Examination as per respective BOS guidelines • ***Separate passing is mandatory for Theory, Internal and Practical Examination***

M.Sc. (Statistics) Programme structure (CBCS PATTERN) (2019-20) M.Sc. Part – II

SEMESTER-III (Duration- Six Month)											
	Sr. No.	Course Code	Teaching Scheme			Examination Scheme					
			Theory and Practical			University Assessment (UA)			Internal Assessment (IA)		
			Lectures (Per week)	Hours (Per week)	Credit	Maximum Marks	Minimum Marks	Exam. Hours	Maximum Marks	Minimum Marks	Exam. Hours
CGPA	1	CC-301	4	4	4	80	32	3	20	8	1
	2	CCS -302	4	4	4	80	32	3	20	8	1
	3	CCS-303	4	4	4	80	32	3	20	8	1
	4	CCS-304	4	4	4	80	32	3	20	8	1
	5	DSE -305	4	4	4	80	32	3	20	8	1
	6	CCPR-306	12	12	4	100	40	*	--	--	-
Total (C)			**--**	**--**	**24**	**500**	**--**	**--**	**100**	**--**	
Non-CGPA	1	AEC-307	2	2	2	--	--	--	50	20	2
	2	EC (SWM MOOC)-308	Number of lectures and credit shall be as specified on SWAYAM MOOC								
SEMESTER-IV (Duration- Six Month)											
CGPA	1	CC-401	4	4	4	80	32	3	20	8	1
	2	CCS -402	4	4	4	80	32	3	20	8	1
	3	CCS-403	4	4	4	80	32	3	20	8	1
	4	CCS-404	4	4	4	80	32	3	20	8	1
	5	DSE -405	4	4	4	80	32	3	20	8	1
	6	CCPR-406	12	12	4	100	40	*	--	--	--
Total (D)			**--**	**--**	**24**	**500**	**--**	**--**	**100**	**--**	**--**
Non-CGPA	1	SEC-407	2	2	2	--	--	--	50	20	2
	2	GE-408	2	2	2	--	--	--	50	20	2
Total (C+D)					**48**	**1000**	**--**	**--**	**200**	**--**	**--**

• Student contact hours per week : **32** Hours (Min.)	• Total Marks for M.Sc.-II : **1200**
• Theory and Practical Lectures : **60** Minutes Each	• Total Credits for M.Sc.-II (Semester III & IV) : **48**
• CC-Core Course • CCS- Core Course Specialization • CCPR-Core Course Practical • DSE-Discipline Specific Elective • AEC-Mandatory Non-CGPA compulsory Ability Enhancement Course • SEC- Mandatory Non-CGPA compulsory Skill Enhancement Course • EC (SWM MOOC) - Non-CGPA Elective Course • GE-Generic Elective	• Practical Examination is annual. • Examination for CCPR-306 shall be based on Semester III Practical. • Examination for CCPR-406 shall be based on Semester IV Practical. • *Duration of Practical Examination as per respective BOS guidelines • ***Separate passing is mandatory for Theory, Internal and Practical Examination***

	M.Sc.-I	**M.Sc.-II**	**Total**
Marks	**1200**	**1200**	**2400**
Credits	**48**	**48**	**96**

I. CGPA course:

1. There shall be 12 Core Courses (CC) of 48 credits per programme.
2. There shall be 06 Core Course Specialization (CCS) of 24 credits per programme.
3. There shall be 02 Discipline Specific Elective (DSE) courses of 08 credits per programme.
4. There shall be 4 Core Course Practical (CCPR) of 16 credits per programme
5. Total credits for CGPA courses shall be of 96 credits per programme

II. Mandatory Non-CGPA Courses:

1. There shall be 02 Mandatory Non-CGPA compulsory Ability Enhancement Courses (AEC) of 02 credits each per programme.
2. There shall be 01 Mandatory Non-CGPA compulsory Skill Enhancement Course (SEC) of 02 credits per programme.
3. There shall be one Elective Course (EC) (SWAYAM MOOC). The credits of this course shall be as specified on SWAYAM MOOC.
4. There shall be one Generic Elective (GE) course of 02 credits per programme. Each student has to take generic elective from the department other than parent department.
5. The total credits for Non-CGPA course shall be of 08 credits + 2-4 credits of EC as per availability.
6. The credits assigned to the courses and the programme are to be earned by the students and shall not have any relevance with the work load of the teacher.

Structure of M. Sc. (Statistics) Programme

Semester I

	Course code	Title of course
CGPA	CC-101	Real Analysis
	CC-102	Linear Algebra
	CC-103	Distribution Theory
	CC-104	Estimation Theory
	CC-105	Statistical Computing
	CCPR-106	Practical I
Mandatory Non-CGPA	Compulsory	AEC: Communicative English-I

Semester II

	Course code	Title of course
CGPA	CC-201	Probability Theory
	CC-202	Theory of Testing of Hypothesis
	CC-203	Regression Analysis
	CC-204	Design and Analysis of Experiments
	CC-205	Sampling Theory and Official Statistics
	CCPR-206	Practical II
Mandatory Non-CGPA	Compulsory	SEC: Fundamentals of Information Technology-I

Semester III

	Course code	Title of course
CGPA	CC-301	Asymptotic Inference
	CCS-302	Multivariate Analysis
		Bayesian Inference
	CCS-303	Stochastic Processes
		Functional Data Analysis
	CCS-304	Data Mining
		Artificial Intelligence
	DSE-305	Time Series Analysis
		Statistical Ecology
	CCPR-306	Practical III
Mandatory Non-CGPA	Compulsory	AEC: Communicative English-II
	Compulsory	EC: SWYAM/ MOOCS

Semester IV

	Course code	Title of course
CGPA	CC-401	Generalized Linear Models
	CCS-402	Survival Analysis
		Actuarial Statistics
	CCS-403	Biostatistics
		Econometrics
	CCS-404	Optimization Techniques
		Circular Data Analysis
	DSE-405	Spatial Data Analysis
		Statistical Quality Control
	CCPR-406	Practical VI and Project
Mandatory Non-CGPA	Compulsory	SEC: Fundamentals of Information Technology-II
	Compulsory	GE: Data Management and Analysis using MSEXCEL

MST 101: Real Analysis (CC-101)

Unit 1: Set of real numbers, countable and uncountable sets, countability of rationals and uncountability of the interval (0,1). Supremum and Infimum of bounded sets, limit point of a set, open, closed, dense and compact sets. Bolzano-Weierstrass and Heine-Borel Theorems (Statements only). Applications of these theorems.

(12 L + 3 T)

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

(12 L + 3 T)

Unit 3: Real valued function, continuous function, Uniform continuity of sequence of functions, Uniform convergence of series of functions with special emphasis on power series, radius of convergence. Riemann, Riemann-Steltjes Integrals and their common properties. Integration by parts, Fundamental theorem on calculus, mean value theorem, their applications in finding functional of distributions.

(12 L + 3 T)

Unit 4: Vector and Matrix differentiation, Maxima, minima of functions of several variables. Constrained maxima, minima, Lagrange's method, Taylor's theorem (without proof), implicit function theorem and their applications. Multiple integrals, Change of variables, Improper integrals, Applications in multivariate distributions. Theorem on differentiation under integral sign and Leibnitz rule (statements only) with applications.

(12 L + 3 T)

References:

1. Malik S. C. &Arora S.(1991): Mathematical Analysis- Wiley Eastern Limited IInd edition.
2. Goldberg R. R. (1964): Methods of Real Analysis- Blaisdell Publishing company, New york, U.S.A.
3. Bartle G. R. (1976): Element of Real Analysis- Wiley, 2nd edition.
4. Bartle G.R. & Sherbert D. R. (2000): Introduction to Real Analysis- JohnWiley & Son Inc.
5. Royden (1988): Principles of Real Analysis - Macmillian.
6. Widder (1989): Advanced Calculus - Dover Publication.
7. Apostol (1985): Mathematical Analysis - Narosa Publishing House, T.M.

MST-102: Linear Algebra (CC-102)

Unit 1: Vector space, subspace, linear dependence and independence, basis, dimension of a vector space, example of vector spaces. Gram-Schmidt orthogonalisation process, Orthonormal basis, orthogonal projection of a vector, Linear transformations, algebra of matrices, types 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.

(12L+3T)

Unit 2: Permutation matrix, reducible/irreducible matrix, primitive/imprimitive 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.

(12L+3T)

Unit 3: 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, Cayley-Hamilton Theorem and its applications.

(12L+3T)

Unit 4: Spectral decomposition of a real symmetric matrix, singular value decomposition, Choleskey decomposition, real quadratic forms, reduction and classification, index and signature, extrema of a quadratic form, simultaneous reduction of two quadratic forms.

(12L+3T)

References:

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

MST-103: Distribution Theory (CC-103)

Unit 1: Cumulative distribution function (CDF), properties of CDF, quantiles, probability density function (PDF), absolutely continuous and discrete distributions, mixtures of probability distributions, decomposition of mixture type CDF into discrete and continuous CDF's, expectation and variance of mixture distributions.

(12L+3T)

Unit 2: Probability Integral transformation. Moment inequalities (with proof): Basic, Holder, Markov, Minkowski, Jensen, Tchebysheff and their applications. Symmetric distributions and their properties, Transformations of univariate random variables, Location, Scale and Shape parameters with examples.

(12L+3T)

Unit 3: Random vectors, joint distributions, Independence, variance-covariance matrix, joint MGF. Conditional expectation and variances, Transformations of bivariate random variables, Bivariate Normal, Marshall-Olkin bivariate exponential distribution. Convolutions, compound distributions.

(12L+3T)

Unit 4: Sampling distributions of statistics from univariate normal random samples, distributions of linear and quadratic forms involving normal random variables, Fisher Cochran theorem, non-central Chi-square, non-central t and F distributions: Expectation, Variance and quantiles.

(12L+3T)

References:

1. Rohatagi V. K. & Saleh A. K. Md. E.(2001) : Introduction to Probability Theory and Mathematical Statistics- John Wiley and sons Inc.
2. Johnson N. L. &Kotz. S. (1996) : Distributions in Statistics Vol-I,II and III, JohnWiley and Sons New york.
3. 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)

MST-104: ESTIMATION THEORY (CC-104)

Unit 1: Sufficiency principle, factorization theorem, minimal sufficiency, minimal sufficient partition, minimal sufficient statistics, minimal sufficient statistic for exponential family, power series family, curved exponential family, and Pitman family, completeness, bounded completeness, ancillary statistics, Basu's theorem and its applications.

(12L + 3T)

Unit 2: Problem of point estimation, unbiased estimators, minimum variance unbiased estimator, Rao-Blackwell theorem and Lehmann-Scheffe theorem and their applications. A necessary and sufficient condition for an estimator to be UMVUE, Fisher information and information matrix, Cramer-Rao inequality, Chapman-Robbins-Kiefer bound, Bhattacharya bounds, their applications.

(12L + 3T)

Unit 3: Maximum likelihood estimator (MLE), properties of MLE, MLE in nonregular families, method of scoring and its applications, method of moments, method of minimum chi-square, U-statistics for expectation and variance; it's simple properties.

(12L + 3T)

Unit 4: The concepts of prior and posterior distributions, conjugate, Jeffrey's and improper priors with examples, Bayes estimation under squared error and absolute error loss functions.

(12L + 3T)

References

1. Rohatgi, V.K. and Saleh, A. K. MD. E. (2015). *Introduction to Probability Theory and Mathematical Statistics* -3rd edition, John Wiley & sons.
2. Lehmann, E. L. (1983). *Theory of Point Estimation* - John Wiley & sons.
3. Rao, C. R.(1973). *Linear Statistical Inference and its Applications*, 2nd edition, Wiley.
4. Kale, B.K. and Muralidharan, K. (2015). *Parametric Inference: An Introduction*, Alpha Science International Ltd.
5. Mukhopadhyay, P. (2015). *Mathematical Statistics*, Books and Allied (p) Ltd.
6. Dudewicz, E. J. andMishra,S. N. (1988). *Modern Mathematical Statistics*, John Wiley and Sons.
7. Casella, G., and Berger, R. L. (2001). *Statistical Inference*, 2nd edition, Duxbury press

MST 105: STATISTICAL COMPUTING (CC-105)

Unit 1: 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 descriptive statistic, computing PMF/PDF, CDF and quantiles of the well known distributions, rand and randbetween function, Logical functions: if, true, false, 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, Introduction to Excel macros.

(12L+3T)

Unit 2: 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, R-packages. R-studio. Building web applications using shiny package.

(12L+3T)

Unit 3: Concept of simulation. Concept of random number generator, true random number and pseudo random number generators, requisites of a good random number generator. Congruential method of generating uniform random numbers. Algorithms for generating random numbers from well known univariate discrete and continuous distributions, generating random vectors from multinomial, bivariate normal, and bivariate exponential distributions, 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.

(12L+3T)

Unit 4: 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 non-linear equations. Numerical integration: quadrature formula, trapezoidal rule and Simpson's rule for single integral.

(12L+3T)

References

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)

MST-117: PRACTICAL –I (CCPR-106)

1. Linear dependence and independence of vectors.
2. Gram-Schmidt orthogonalization method.
3. Solving systems of equations.
4. Inverse of a matrix.
5. Applications of Cayley-Hamilton theorem.
6. Characteristics roots and vectors and their applications.
7. Classifications and reduction of quadratic forms.
8. Sketching of d.fs.
9. Finding best possible probability distribution to observed data sets and allied inferences.
10. Construction of UMVUE
11. Maximum likelihood and method of moments estimation
12. Methods of Scoring and method of minimum chi-square estimation
13. Baysian estimation

14 – 19. Programming assignments on CC–105 Course. (Software to be used: R/MINITAB/MATLAB/SAS/SYSTAT depends on availability)

Semester II

MST 201: PROBABILITY THEORY (CC-201)

Unit 1: 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 $\mathcal{R}$. Computation of probabilities of arbitrary events using distribution function. Independence of events.

(12L+3T)

Unit 2: Measurable function, 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) and their applications.

(12L+3T)

Unit 3: 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 and its 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.

(12L+3T)

Unit 4: 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.

(12L+3T)

References:

1. Bhat B. R.(1981) : Modern Probability Theory –IIIrd edition :New age international (P)limited,

2. Alan Karr,(1993) : Probability Theory – Springer Verlag.

3. Billingsley P.(1986) : Probability & Measure –John Wiley and sons

4. AthreyaK. B. and Lahiri S. (2006). Probability Theory vol 41, Trim series, (Hindustan Book Agency).

5. Feller, W. (1969). Introduction to Probability and its Applications vol.II (Wiley Eastern Ltd.)

6. Loeve, M. (1978). Probability Theory (Springer Verlag). Fourth edition

7. Rohatgi, V.K. and Saleh, A. K. MD. E. (2015).Introduction to Probability Theory and Mathematical Statistics -3rd Edition, John Wiley & sons.

MST-202: THEORY OF TESTING OF HYPOTHESES (CC-202)

Unit 1: 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 test, UMP test for one-sided alternatives. Concept of p-value.

(12L+3T)

Unit 2: UMP tests for two sided alternatives, examples of 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.

(12L+3T)

Unit 3: Problem of confidence intervals, relation with testing of hypotheses problem, UMA and UMAU confidence intervals, shortest length confidence intervals. Likelihood ratio test and its applications.

(12L+3T)

Unit 4: Goodness of fit tests based on Chi-square distribution and application to contingency tables. Non-parametric tests, One and two sample problem; one sample tests: Sign test, Wilcoxon Signed-Rank test. Two sample tests: Wald-Wolfowitz Runs test, Mann-Whiteny U test, Median test, Kolmogorov Smirnov test. Spearman's Rank Correlation Test; Kendall's Rank Correlation Test; Kruskal-Wallis Test.

(12L+3T)

References:

1. Rohatgi, V.K. and Saleh, A. K. MD. E. (2015).Introduction to Probability Theory and Mathematical Statistics -3rd Edition, John Wiley & sons.
2. Kale, B. K. and Muralidharan, K. (2015). Parametric Inference: An Introduction, Alpha Science International Ltd.
3. Dudewicz, E. J. and Mishra, S. N. (1988). Modern Mathematical Statistics, John Wiley and Sons.
4. Lehman, E. L. (1987). Theory of testing of hypotheses. Students Edition.
5. Ferguson, T. S. (1967). Mathematical Statistics: A decision theoretical approach.Academic press.
6. Zacks, S. (1971) .Theory of Statistical Inference, John Wiley and Sons, NewYork.
7. Randles, R. H. and Wolfe, D. A. (1979).Introduction to theory of nonparametric Statistics, Wiley.
8. Gibbons J. D. and Chakraborti S.(2010) Nonparametric Statistical Inference, Fifth Edition,CRC Press.

MST-203: REGRESSION ANALYSIS (CC-203)

Unit-1: 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. Residuals and their properties, residual diagnostics. Transformation of Variables: VST and Box-Cox power transformation. (12L+3T)

Unit-2: Variable Selection Procedures: R-square, adjusted R-square, Mallows' Cp, forward, backward and stepwise selection methods, AIC, BIC. Multicollinearity: Consequences, detection and remedies, ridge regression. Autocorrelation: sources, consequences, detection (Durbin-Watson test) and remedies. Parameter estimation using Cochrane-Orcutt method. (12L+3T)

Unit-3: Robust Regression: Influential observations, leverage, outliers, methods of detection of outliers and influential observations, estimation in the presence of outliers: M-estimator, Huber loss function, breakdown point, influence function, efficiency, Asymptotic distribution of M-estimator (Statement only), Mallows' class of estimators.

(12L+3T)

Unit-4: Nonlinear regression models: Non linear least squares, Transformation to a linear model, Parameter estimation in a non linear system, Statistical inference in non linear regression. Polynomial regression model, piecewise polynomial fitting, nonparametric regression: kernel and locally weighted regression.

(12L+3T)

References

1. Draper N.R. and Smith, H. (1998): Applied Regression Analysis. 3rd ed Wiley
2. Wiesberg, S. (1985): Applied Linear Regression, Wiley.
3. Kutner, Neter, Nachtsheim and Wasserman (2003): Applied Linear Regression Models, 4th Edition, McGraw-Hill
4. Montgomery, D.C., Peck, E.A.,and Vining, G.(2012): Introduction to Linear Regression Analysis, 5th Ed . Wiley
5. Cook R.D. &WiesbergS.(1982): Residuals and Influence in Regression. Chapman and Hall.
6. Birkes, D and Dodge, Y. (1993). Alternative methods of regression, John Wiley & Sons.
7. Huber, P. J. and Ronchetti, E. M (2011) Robust Statistics, Wiley, 2nd Edition.
8. Seber, G. A., Wild, C. J. (2003). Non linear Regression, Wiley.

MST-204: DESIGN AND ANALYSIS OF EXPERIMENTS (CC-204)

Unit 1: General linear model: definition, assumptions, concept of estimability, least squares estimation, BLUE, estimation space, error space, Guass Markov theorem, variances and covariances of BLUEs, Tests of hypotheses in general linear models. Simultaneous testing of general linear hypotheses: Bonferroni, Tukey's , Scheffé's tests, Fisher least significant difference method; applications to CRD and RBD .

(12L + 3T)

Unit 2: Concepts of factorial designs, main effects, and interaction effects; Two-factor factorial design and its analysis using fixed effect model; 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, IV, and V designs; fold over designs; saturated designs.

(12L + 3T)

Unit 3: 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.

(12L + 3T)

Unit 4: Response surface methodology: the method of steepest ascent, analysis of the response surface, characterizing the response surface, ridge systems, multiple responses, designs for fitting response surfaces; Robust parameter design: crossed array designs and their analyses, combined array designs and the response model approach.

(12L + 3T)

References

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.

MST-205: Sampling Theory and Official Statistics (CC-205)

Unit 1: Review of basic methods: simple random sampling and stratified random sampling, Use of supplementary information for estimation, ratio and regression estimators with their properties and generalizations, Double sampling procedures and their ratio and regression estimators. Systematic sampling, Cluster sampling, multistage-sampling.

(12L + 3T)

Unit 2: Varying probability sampling: PPS sampling, Cumulative total method, Lahiri's method, Hansen-Horwitz estimator and its properties. Horwitz- Thompson, Des Raj estimators for a general sample size and Murthy's estimator for a sample of size 2 and its properties. Midzuno sampling, Rao-Hartley-Cochran sampling Strategy.

(12L + 3T)

Unit 3: Non - sampling errors: Response and non- response errors. Hansen–Horwitz and Demings model for the effect of call-backs. Randomised 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. (12L + 3T)

Unit4 : Elements of Indian Official Statistics including various national level surveys, National Accounts – different approaches, Indices for Development, Evaluation & Monitoring

(12L + 3T)

References

1. Parimal Mukhopadhyay (2008): Theory and methods of survey sampling – 2ndEdition, Prentice Hall of India private limited.
2. Sukhatme P. V., Sukhatme S. & Ashok C (1984): Sampling Theory of surveys and applications – Iowa university press and Indian society of agricultural statistics, New Delhi.
3. Chaudhuri and H. Stenger (2005): Survey Sampling: Theory and Methods, 2nd edition, chapman and hall/CRC.
4. Des Raj and Chandhok. P. (1998): Sample Survey Theory - Narosa publication.
5. William G. Cochran. (2008): Sampling Techniques- IIIrd edition –John and Wieleysons Inc.
6. Singh, D. and Chaudhary F.S (1986).Theory and Analysis of Sample Survey Designs, Wiley Eastern Limited.
7. UNDP (2010) Human Development in India: Analysis to Action
8. UNDP (2015) Training Material for Producing National Human Development Reports
9. UNDP (2016) Human Development Report 2016
10. The 2010 Human Development Index (HDI): Construction and Analysis
11. CSO. National Accounts Statistics- Sources and Health.
12. Sen, A. (1997). Poverty and Inequality.
13. Datt R., Sundharam, K. P. M. (2016) Indian Economy, (Sultan Chand & company Ltd.)

MST-216: PRACTICAL –II (CCPR-206)

1. M.P. UMP, and UMPU Tests
2. Likelihood ratio tests
3. Confidence Intervals
4. Non-parametric Tests
5. Multiple linear regression
6. Variable selection
7. Multicollinearity and Autocorrelation
8. Detection of Influential observations and M-estimation
9. Nonlinear and Nonparametric regression
10. Linear Estimation: Estimation and Hypothesis testing
11. Analysis of 2^k full factorial designs
12. Analysis of confounded 2^k factorial design and 2^{k-p} fractional factorial designs
13. Analysis of 3^k full factorial, confounded, and 3^{k-p} fractional factorial designs
14. Analysis of response surfaces and Taguchi designs.
15. Basic sampling designs.
16. Ratio and regression method of estimation
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 each of the following software EXCEL/ R/ MINITAB/ MATLAB/ SYSTAT /SAS wherever applicable.)