

## Statistics (सांख्यिकी) PGSTAT

Year	Paper No.	Course Code	Title of the Course	Credits	Compulsory Elective	
<b>Compulsory Core Course</b> विषय केन्द्रित अनिवार्य पाठ्यक्रम						
प्रथम वर्ष (1st Year)	5176	PGSTAT-01	Probability and Distribution	4	अनिवार्य	
	5177	PGSTAT-02	Statistical Inference	4		
	5178	PGSTAT-03	Linear Models and Design of Experiments	4	अनिवार्य	
	5179	PGSTAT-04	Survey Sampling	4		
	5180 5181	PGSTAT-05 PGSTAT-06 (P)	Stochastic Process Practical Based on PGSTAT- 01, 02, 03, & 04	4 4	अनिवार्य	
<b>Discipline-Centric Elective Course/ विषय केन्द्रित वैकल्पिक पाठ्यक्रम (Select any two with 04+04=8 Credits)</b>						
	5182 or 5183 or 5184 or 5185	PGSTAT-07 or PGSTAT-08 or PGSTAT-09 or PGSTAT-10	Mathematical Analysis or Measures Theory or Survival Analysis or Reliability Theory	4 or 4 or 4 or 4	वैकल्पिक	
<b>Open Elective Course (Other Disciplines)/ अन्य विषय केन्द्रित वैकल्पिक पाठ्यक्रम</b>						
	5186 or 5187	PGSTAT-11 or PGSTAT-12	<b>Operation Research</b> or <b>Linear Algebra</b>	8 or 8	वैकल्पिक	
प्रथम वर्ष का कुल क्रेडिट					<b>40</b>	
<b>Compulsory Core Course/ विषय केन्द्रित अनिवार्य पाठ्यक्रम</b>						
द्वितीय वर्ष	5188 5189	PGSTAT-13 PGSTAT-14	Decision Theory Multivariate Analysis	4 or 4	अनिवार्य	
	5190 5191	PGSTAT-15 PGSTAT-16	Non-Parametric Econometrics	4 or 4		
	5192 5193	PGSTAT-17 PGSTAT-18 (P)	Demography Practical Based on PGSTAT-14, 15, 16 and 17	4 or 4	अनिवार्य	
	<b>Discipline Centric Course/ विषय केन्द्रित पाठ्यक्रम</b>					
	5194	PGSTAT-19 (PW)	Project Work	8	अनिवार्य	
	<b>Open Elective Course (Other Discipline)/ अन्य विषय केन्द्रित वैकल्पिक पाठ्यक्रम</b>					
	5195 or 5196	PGSTAT-20 or PGSTAT-21	Research Methodology in Social Behavior Sciences or Statistical Software	8 or 8	वैकल्पिक	
	<b>Compulsory Foundation Course/ अनिवार्य आधार पाठ्यक्रम</b>					
	2702	PGFGS	Gadhian Thoughts and Peace Studies	नॉन	अनिवार्य	

	or 2703	or PGFHR	गाँधियन विचार एवं शान्ति शिक्षा Or Human Rights and Duties मानवाधिकार एवं कर्त्तव्य	क्रेडिट	
द्वितीय वर्ष का कुल क्रेडिट					<b>40</b>
सम्पूर्ण कार्यक्रम का कुल क्रेडिट					<b>80</b>

M.Sc. (Statistics) / M.A. (Statistics)

PGSTAT-01 / MASTAT-01 (Old)

PGSTAT-07 / MASTAT-07 (New)

## Mathematical Analysis

### Block 1- Riemann Stieltjes Integrals, Fourier Series and Functions of Bounded Variation

#### Unit 1: Riemann Stieltjes Integrals

Absolutely continuous functions. Riemann Stieltjes integrals. Basic theorems. Definitions, Linear properties, integration by parts, change of variable in . Riemann Stieltjes integrals, upper and lower integrals, necessary and sufficient conditions for existence of . Riemann Stieltjes integrals, integral as a function of parameters, differentiation under the integral sign.

#### Unit 2: Fourier Series

Fourier Series, orthogonal system of functions, Fourier series of a function relative to an orthogonal system, properties of Fourier Coefficients, Reusz- Fischer theorem, convergence and representation problems for Fourier Metric Series, Sufficient conditions for convergence of Fourier Series at a particular point.

#### Unit 3: Bounded Variation

Functions of bounded variation, total variation, function of bounded variation expressed as the difference of increasing functions, continuous functions of bounded variation, Absolutely continuous functions.

### Block 2- Metric Spaces & Continuity

#### Unit 4: Metric Spaces

Metric Spaces, open and closed sets, limit and cluster points, Cauchy Sequences and completeness,

Convergence of sequences, Completeness of  $\mathbb{R}^n$ . Baire's theorem. Cantor's ternary set as example of a perfect set which is nowhere dense.

#### Unit 5: Continuity

Continuity and uniform continuity of a function from a Metric space to a Metric space. Open and closed maps, Compact spaces and compact sets with their properties. Continuity and compactness under continuous maps.

PGSTAT-02 / MASTAT-02 (Old)

PGSTAT-01 / MASTAT-01 (New)

## Probability and Distribution

### Block 1- Probability Measure, Distribution Function and Inequalities

#### Unit 1: Probability Measure and Distribution Functions

Probability space of a random experiment .probability measures, random variables as a measurable function. Field induced by a sequence of random variables, decomposition of distribution functions in purely discrete, absolutely continuous and singular components.

### **Unit 2: Probability Inequalities**

CR-inequality, Cauchy-Schwartz inequality, Holder inequality, Minkowski inequality, Jensen inequality, Lyapunov inequality, Kolmogorov inequality, Hajck-Renyki inequality.

## **Block 2- Convergence, Characteristics Function and Limit Theorems**

### **Unit 3: Convergence**

Sequences of distribution functions, Helly - Bray theorem, Different types of convergence of sequence of random variables distribution function of random vectors, Weak and strong law of large numbers, Khinchin. Borel and Kolmogorav theorems.

### **Unit 4: Characteristic Function and Central Limit Theorems**

Borel-Cantelli lemmas and zero-one law, Characteristic function, Inversion theorem, Continuity theorem, One dimensional central limit problem: lindeberg-levy, Lyapunov, Lindeberg-Feller theorems.

**PGSTAT-03 / MASTAT-03 (Old)**

**PGSTAT-02 / MASTAT-02 (New)**

## **Statistical Inference**

### **Block 1 - Estimation Theory**

#### **Unit 1: Sufficiency, Completeness and Exponential Family**

Estimation: Sufficiency, Completeness, Rao-Blackwell theorem, Lehman Schaffer theorem, Cramer-Rao inequality minimal sufficiency, Completeness, Bounded completeness, Ancillary statistics, Basu's theorem on independence of Statistics, Exponential family

#### **Unit 2: Methods of Estimation and Criterion for Good Estimators**

Bhattacharya bound, Chapman Robbins and Kiefer (CRK) bound, maximum likelihood estimation, Zehna theorem for invariance, Cramer theorem for weak consistence, asymptotic normality, BAN and CAN estimators, asymptotic efficiency.

### **Block 2: Confidence Estimation and Hypothesis Testing**

#### **Unit 3: Confidence Estimation**

Confidence interval and confidence coefficient, shortest length confidence interval, relation between confidence estimation and hypotheses testing.

#### **Unit 4: Hypothesis Testing**

Generalized Neyman Pearson lemma, UMP tests for distributions with MLR, LR tests and their properties, UMPU tests, similar regions, Neyman structure, Invariant tests.

## **Linear Models and Design of Experiments**

### **Block 1 - Linear Estimation and Analysis of Variance**

#### **Unit 1: Linear Model and BLUE**

Linear Estimation- estimable functions, estimations and error space, Best linear unbiased estimate (BLUE), Markov theorem distribution of quadratic form, Estimable linear hypotheses generalized F and T tests.

#### **Unit 2: Analysis of Variance**

Analysis of Variance : Two-way classification with equal number of observation per cell and Tukey's test general two-way classification, Analyses of covariance,

### **Block 2 - Design of Experiment**

#### **Unit 3: Factorial Experiments**

$2^n$ ,  $3^2$  and  $3^3$  factorial experiments complete and partial confounding.

#### **Unit 4: BIBD and Split Plot Design**

Balanced Incomplete Block Design (BIBD), construction of BIBD, intra block and inter block analysis, split plot design.

## **Survey Sampling**

### **Block 1 - Random Sampling Procedures**

#### **Unit 1: Stratified Sampling and Use of Auxiliary Information**

Sampling Theory: stratified sampling, Post-stratification and deep stratification, Methods of allocation, ratio and regression estimators, double sampling in ratio and regression estimation.

#### **Unit 2: Cluster and Multi-Stage Sampling**

Cluster sampling with equal clusters two stage and multi-stage sampling, Non sampling errors.

### **Block 2 - Varying Probability Sampling**

#### **Unit 3: Methods of Selection and Ordered Estimators**

Varying probability sampling with and without replacement, cumulative total and Lahiri's methods of selection, Estimation of population mean, Desraj ordered estimates.

## **Unit 4: Unordered Estimators**

Horvitz-Thompson estimator, Midzuno and Narain system of sampling.

**PGSTAT-08 / MASTAT-08 (Old)**  
**PGSTAT—05 / MASTAT- 05 (New)**

## **Stochastic Process**

### **Block 1: Markov Chains**

#### **Unit 1: Markov Dependent Trials and Transition Probabilities**

Two state Markov sequences, Markov chains, determination of n-step transition probabilities, Chapman-Kolmogorov equations, first return and first passage probabilities.

#### **Unit 2: Classification of States**

Classification of states, communication states, periodicity, stationary probability distributions and limit theorems for Ergodic chains.

### **Block 2: Continuous Time Markov Processes and Branching Processes**

#### **Unit 1: Continuous Time Markov Processes**

Continuous time Markov processes. Poisson (point) process, birth and death processes, random walk and gambler's ruin problem.

#### **Unit 2: Branching Processes**

Simple branching process, probability generating function and moments of number of individuals in the n-th generation, fundamental theorem of probability of extinction.

**PGSTAT-07(P) / MASTAT-07(P) (Old)**  
**PGSTAT—06(P) / MASTAT- 06(P) (New)**

**Practical based on PGSTAT- 03, 04, 05 / MASTAT- 03, 04, 05 (Old)**  
**Practical based on PGSTAT- 01, 02, 03 & 04 / MASTAT- 01, 02, 03 & 04 (New)**

**PGSTAT-08 / MASTAT – 08 (New)**

## **Measures Theory**

### **Block – 1: Measure Theory**

#### **Unit - 1 Measure**

Field,  $\sigma$ -Field, Borel field. Measure, Measure on  $\mathbb{R}^n$ , Properties of measure, Outer Measure, Extension of measures, Extension Theorem, Outer Extension. Simple functions, Integration, Non-negative integrable functions, Integrable measurable functions.

### **Unit – 2: Convergence**

Measure Space, Measurable Functions, Combinations of measurable function, point wise Convergence, Convergence in measure.

### **Unit – 3: Signed Measures**

Signed measures, Hahn and Jordan decomposition, Absolute Continuity, The Radon-Nikodym theorem, Derives of Signed Measures. Product Space, Cartesian products of two measurable spaces, Section, Product measures,

### **Unit – 4:**

Fubini's theorem, Lebesgue-Stieltjes measure, Lebesgue-stieltjes integral, Riemann-stieltjes integration.

### **Block – 2: Real Analysis**

#### **Unit – 1:**

Recap of elements of set theory; Introduction to real numbers, Introduction to n-dimensional Euclidian space; open and closed intervals (rectangles), compact sets, Bolzano - Weirstrass theorem, Heine – Borel theorem. Sequences and series; their convergence. Real valued functions, continuous functions; uniform continuity, sequences of functions, uniform convergence; Power series and radius of convergence.

#### **Unit – 2:**

Differentiation, maxima - minima of functions; functions of several variables, constrained maxima - minima of functions. Multiple integrals and their evaluation by repeated integration. change of variables in multiple integration. Uniform convergence in improper integrals, differentiation under the sign of integral - Leibnitz rule.

## **PGSTAT-09 / MASTAT – 09 (New)**

### **Survival Analysis**

Concepts of time, Order and random Censoring, likelihood in these cases. Life distributions-Exponential Gamma, Weibull, Lognormal, Pareto, Linear Failure rate. Parametric inference (Point estimation, Confidence Intervals, Scores, LR, MLE tests (Rao-Willks-Wald)) for these distributions. Life tables, failure rate, mean residual life and their elementary properties. Ageing classes - and their properties, Bathtub Failure rate. Estimation of survival function - Actuarial Estimator, Kaplan -Meier Estimator, Estimation under the assumption of IFR/DFR. Tests of exponentiality against non-parametric classes- Total time on test, Deshpande test. Two sample problem-Gehan test, Log rank test. Mantel-Haenszel test, Tarone – Ware tests. Semi-parametric regression for failure rate - Cox's proportional hazards model with one and several covariates. Rank test for the regression coefficients. Competing risks model, parametric and non-parametric inference for this model. Multiple decrement life table.

## **PGSTAT-10 / MASTAT – 10 (New)**

# Reliability Theory

Reliability concepts and measures; components and systems; coherent systems; reliability of coherent systems; cuts and paths; modular decomposition; bounds on system reliability; structural and reliability importance of components. Life distributions; reliability function; hazard rate; common life distributions-Exponential, Weibull, Gamma, Paratto, Chauchy etc. Estimation of parameters and tests in these models. Notions of ageing; IFR, IFRA, NBU, DMRL, and NBUE Classes and their duals; loss of memory property of the exponential distribution; closures or these classes under formation of coherent systems, convolutions and mixtures. Univariate shock models and life distributions arising out of them; bivariate shock models; common bivariate exponential distributions and their properties.

Reliability estimation based on failure times in variously censored life tests and in tests with replacement of failed items; stress-strength reliability and its estimation.

Maintenance and replacement policies; availability of repairable systems; modeling of a repairable system by a non-homogeneous Poisson process. Reliability growth models; probability plotting techniques; Hollander-Proschan and Deshpande tests for exponentiality; tests for HPP vs. NHPP with repairable systems. Basic ideas of accelerated life testing.

## PGSTAT-11 / MASTAT – 11 (New)

### Operation Research

#### **Block – 1: Linear & Non-Linear Programming**

**Unit - 1** Review of LP Problems, Methods of Solution, Duality Theorem, Transportations & Assignment Problems with Proof of Relevant Results

**Unit – 2** Methods Using Artificial Variables, Two Phase and Penalty, Degeneracy & Cycling, Sensitivity Analysis.

**Unit - 3** Non-Linear Programming, Kuhn Tucker Theorem, Wolfe's and Beale's Algorithm for Solving Quadratic Programming, Bellman's Principle of Optimality

#### **Block – 2: Theory of Games & Sequencing & Network Analysis**

**Unit - 1** Games in Normal and Extended forms, Fundamental Theorem of Matrix Games, Solution of  $2 \times 2$ ,  $2 \times m$  and  $M \times n$  Zero-sum games by Dominance Principles.

**Unit - 2** Sequencing and Scheduling Models, 2 Machine, n-Job Problem (no passing), 3 machine, n-job problems, different routing- 2 jobs & m stations, travelling sales-man problem.

**Unit - 3** Introduction to networks, determination of flows and of critical paths, CPM & PERT

#### **Block - 3: Queuing Theory**

**Unit - 1** Queuing models- Specification & Effectiveness Measures, the  $E_k/M/1$ ,  $M/E_k/1$ ;  $M/M/1$ ;  $M/M/c$  &  $M/G/1$  Queues, and their Steady State Solutions

**Unit - 2** Machine Interference Problem, Waiting Time Distribution for  $M/M/1$  and  $M/M/C$  models



## **Block – 4: Replacement Problems**

**Unit - 1** Replacement Problems, Replacement of items that Depreciate, Discounted Cash Flow in Investment Problems.

**Unit - 2** Replacement of items Failing According to a Probability Law; block and age replacement policies, Staffing Problem, Dynamic Programming Approach for Maintenance Problems.

### **PGSTAT-12 / MASTAT – 12 (New)**

## **Linear Algebra**

Fields, vector spaces, subspaces, linear dependence and independence, basis and dimension of a vector space, finite dimensional vector spaces, completion theorem, examples of vector spaces over real and complex fields, linear equations. Vector spaces with an inner product, Gram-Schmidt orthogonalization process, orthonormal basis and orthogonal projection of a vector. Linear transformations, algebra of matrices, row and column spaces of a matrix, elementary matrices, determinants, rank and inverse of a matrix, null space and nullity, partitioned matrices, Kronecker product. Hermite canonical form, generalized inverse, Moore-Penrose generalized inverse, Idempotent matrices, Solutions of matrix equations. Real quadratic forms, reduction and classification of quadratic forms, index and signature, triangular reduction of a positive definite matrix.

Criteria in selecting factorial designs: Criteria based on the Spectrum of the information matrix-A and D-optimality, criteria based on alias matrix.

Construction of layouts of orthogonal array experiments and associated linear graphs to study some of the main effects and first order interactions of  $2^k$  designs which need not be resolution 3 designs, (designs known as Taguchi designs) with special cases of  $L_8$ , and  $L_{16}$ .

$3^k$  Full factorial designs, . Total and partial confounding in  $3^k$  Factorial experiments. Construction of Orthogonal array experiments involving three level factors, with special cases of  $L_9$  , and  $L_{18}$ .

Roll of Center Composite Designs (CCD) as alternative to  $3^k$  designs, rotatability of CCD, Linear and quadratic Response surfaces, contour plots.

Roll of non normality, Box- Cox transformation, Generalized linear models(GLIM), For exponential family of distributions,

### **PGSTAT-09 / MASTAT-09 (Old)** **PGSTAT—13 / MASTAT- 13 (New)**

## **Decision Theory**

### **Block 1: Basic Elements and Bayes Rules**

#### **Unit 1: Basic Elements**

Decision theoretic problem as a game, basic elements, optimal decision rules, unbiased ness, invariance, ordering.

#### **Unit 2: Bayes and Minimax Rules**

Bayes and minimax principles, generalized. Bayes rules, extended Bayes rules,

## **Block 2: Optimality of Decision Rules**

### **Unit 3: Admissibility and Completeness**

Admissibility, completeness, minimal complete class, separating and supporting hyper plane theorems,

### **Unit 4: Minimality and Multiple Decision Problems**

Minimax theorem, complete class theorem, equalizer rules, examples, multiple decision problems.

**PGSTAT-10 / MASTAT-10 (Old)**  
**PGSTAT—14 / MASTAT- 14 (New)**

## **Multivariate Analysis**

### **Block 1: Multivariate Normal Distribution and Estimation of Parameters**

#### **Unit 1: Multivariate Normal Distribution**

Multivariate normal distribution, Characteristic function, marginal and conditional distributions, multiple and partial correlation coefficient.

#### **Unit 2: MLE of Parameters and Sampling Distributions of Multiple and Partial Correlations**

Maximum likelihood estimators of the mean vector and covariance matrix, sample Multiple and partial correlation coefficients and their null sampling distributions

### **Block 2: Distributions Related to MND and their Applications**

#### **Unit 3: Wishart Distribution and Hotelling's $T^2$**

Wishart distribution. Its characteristic function, additive property of Wishart distribution, Hotelling's  $T^2$  and its applications

#### **Unit 4: Mahalanobis $D^2$ and Discriminant Analysis**

Mahalanobis  $D^2$  and its various applications, Discriminant analysis.

**PGSTAT-11 / MASTAT-11 (Old)**  
**PGSTAT—15 / MASTAT- 15 (New)**

## **Nonparametrics**

### **Block 1- Order Statistics**

#### **Unit 1: Basic Distribution Theory**

Order statistics, Distribution of maximum, minimum and r-th order statistic, Joint distribution of r-th and s-th order statistic,

## **Unit 2: Distribution Free Intervals**

Distribution of range function of order statistics, distribution free confidence intervals for quintiles, distribution free tolerance interval, Fooleries limits.

## **Block 2- Non- Parametric Tests**

### **Unit 3: One- sample and Two Sample Location Tests**

Sign test. Wilcoxon test, Median test,

### **Unit 4: Other non- parametric tests**

one sample and two sample location tests. Mann- Whitney U- Test, Application of U-statistic to rank tests. One sample and two sample Kolmogorov-Smirnov tests. Run tests. Pitman ARE.

PGSTAT-12 / MASTAT-12 (Old)  
PGSTAT—16 / MASTAT- 16 (New)

## **Econometrics**

### **Block 1: Linear Model and its generalizations**

#### **Unit 1: Linear regression models, estimation of parameters and prediction**

Linear regression model. Assumptions, estimation of parameters by least squares and maximum likelihood methods tests of hypotheses and confidence estimation for regression coefficients,  $R^2$  and adjusted  $R^2$ , point and interval predictors

#### **Unit 2: Model with qualitative independent variables and non-spherical disturbances**

Use of dummy variables, model with non-spherical disturbances, estimation of parametric by generalized equation, Seemingly unrelated regression equations (SURE) model and its estimation

### **Block 2: Simultaneous equations model**

#### **Unit 3: Structural and reduced form of the model and identification problem**

Simultaneous equations model, concept of structural and reduced forms, problem of identification, rank and order conditions of indentifiability

#### **Unit 4: Estimation in simultaneous equation models**

Limited and full information estimators, indirect least squares estimators, two stage least squares estimators, three stage least squares estimators.

## Demography

### Block -1. Migration

- Unit-I** : Introduction, Estimation of life time and inter-censal migration from place of birth statistics, estimation of internal migration from statistics on duration of residence, at a fixed proor date.
- Unit -2** : Indirect measure of net internal migration based on growth rate method, methods to estimate intercensal migration-using vital statistics, life time survival ratio method and census survival methods, estimation of international migration.

### Block-2. Stable Population Theory

- Unit-1** :Introduction, basic concepts of stable, quasi-stable, stationary and non-stable populations, vital rates and characteristics of stationary stable population and quasi-stable population.
- Unit-2** : Definition of intrinsic rates of natural increase, intrinsic birth rate and intrinsic death rate, their relationship, derivation of Lotka's formulae of fundamental relationship instable population.
- Unit-3** : Computation of intrinsic rate of natural increase and construction of stable age distribution from the given fertility and mortality schedules, relationship between net reproduction rate(NRR), intrinsic rate of natural increase and mean length of generation, concept of mean interval between two generations.

### Block-3.Fertility & Fertility Models.

- Unit-1** : Introduction, crude birth rate (CBR), gross fertility rate (GFR,) age specific fertility rate) ASFR), total fertility rate (TFR), gross reproduction rate (GRR)
- Unit-2** : Period and cohort measures, use of birth order statistics, child women ratio, own-children method, children ever born(CEB) data and with data on current fertility, Brass P/F ration for adjusting fertility rates.
- Unit-3** : Simple model on time of first birth/conception and number of births/conception n specified time, birth interval models, study of fertility through birth interval analysis.

### Block-4.: Mortality

- Unit-1** : Introduction, crude death rate (CDR), specific death rates (SDR), standardized death rate (STDR).

**Unit-2** : Life table, abridge life table, model life table of UNO (old and new), coale and demny model, brass model through logit transformation.

**PGSTAT-14(P) / MASTAT-14(P) (Old)**  
**PGSTAT-18(P) / MASTAT – 18 (P) (New)**

**Practical Based on PGSTAT / MASTAT-10 , 11, 12 & 13 (Old).**  
**Practical Based on PGSTAT / MASTAT-14 , 15, 16 & 17 (New).**

**PGSTAT-19(PW) / MASTAT – 19 (PW)**

**Project Work**

**PGSTAT-20 / MASTAT – 20**

**Research Methodology in Social Behavior Sciences**

About Meaning of Research, Types of Research, Criteria of Good Research, Research Problem, Research Design, Basic Principles of Experimental Designs.

Sampling Design, Criteria of Selecting a Sampling Procedure, Simple Random Sample Design, Complex Random Sample Design, Measurement and Scaling Techniques, Methods of Data Collection, Processing and Analysis of Data.

Discriptive Statistics, Measures of Central Tendency, Measures of Dispersion, Measures of Asymmetry, Measures of Relationships, Association of Attributes.

Testing of Hypothesis for Parametric Tests, Testing of Hypothesis for Non-Parametric Tests, Analysis of Variance and Analysis of Covariance, Chi-Square Test, Multivariate Analysis Techniques, Factor Analysis.

Meaning of Interpretation, Significance of Report Writing, Report Writing..

**PGSTAT-21 / MASTAT – 21**

**Statistical Softwares**

About Statistical Softwares, its features and the steps for data analysis with related softwares. SPSS, STATISTICA, STATA, R, R-Commander, MATLAB.