YEAR 3: SEMESTER **V**

Course ode	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-5.1-T ST-M-5.1-P	Inference-II and Large Sample Theory (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-M-5.2-T ST-M-5.2-P	Survey Sampling and Official Statistics (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-MI-5.1-T ST-MI-5.1-P	Applied Statistics (Theo & Prac)	Minor	3+1=4	4	7	3	28	12	50
ST-MI-5.2-T	Sampling Distribution (Theo)	Minor	4	4	10	-	40	-	50
Total			20	20	50		200		250

YEAR 3: SEMESTER **VI**

Course Code	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-6.1-T ST-M-6.1-P	Multivariate Analysis and Nonparametric Techniques (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-M-6.2-T ST-M-6.2-P	Linear Models and Design of Experiments (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-M-6.3-T ST-M-6.3-P	Economic Statistics (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-OU-3/ ST-SI-3	Outreach/ Internship	Outreach/ Internship	2	2					
Total			20	20	45		180		225

Same as Semester III

YEAR 3: SEMESTER 5

Paper: ST-M-5.1-T Inference II and Large Sample Theory (Theoretical) Course Type:

Major Credit 4 Marks 50

Unit 1

Principles of hypothesis testing: Null and alternative hypotheses (simple and composite), Type-I and Type-II errors, critical region, level of significance, size and power.
Best critical region, most powerful test, uniformly most powerful test, Neyman-Pearson Lemma (statement, proof of sufficiency part and applications to construct most powerful tests and uniformly most powerful tests). Unbiased test, Definition of UMPU test.
Likelihood ratio test, properties of likelihood ratio tests (without proof). (16L)

Unit 2

Sequential Analysis: Sequential probability ratio test (SPRT) for simple vs. simple hypotheses. Fundamental relations among α, β, A and B, determination of A and B in practice. Wald's fundamental identity and the derivation of operating characteristics (OC) and average sample number (ASN) functions, examples based on normal, Poisson and binomial distributions. (10L)

Unit 3

Notion of convergence in probability and in law, statement of Slutsky's theorem, Chebyshev's WLLN, Central Limit Theorem (CLT), use of CLT for deriving large sample tests for binomial proportions, difference of two binomial proportions, mean of a population and difference of means of two independent populations. Related confidence intervals. (8L)

Large sample standard error; derivation of large sample standard error of a function of statistics in the multiparameter situation, sample moments, standard deviation, coefficient of variation and correlation coefficient. (6L)

Unit 4

Transformation of statistics to stabilize variance: derivations of $\sin^{-1}$, square-root, logarithmic and z-transformation and their uses in large sample tests and interval estimation.

Large sample distribution of Pearsonian $\chi 2$ -statistic and its uses in test of independence, homogeneity and goodness of fit.

Paper: ST-M-5.1-P Inference II and Large Sample Theory (Practical) Course Type:

Major Credit 2 Marks 25

List of Practical
1. Probabilities of Type I and Type II errors
2. Most powerful critical region (NP Lemma)

3. Uniformly most powerful critical region
4. Unbiased critical region
5. Power curves
6. Likelihood ratio tests for simple null hypothesis against simple alternative hypothesis
7. Likelihood ratio tests for simple null hypothesis against composite alternative hypothesis

8. SPRT procedure
9. OC function and OC curve
10. ASN function and ASN curve
11. Large sample tests for binomial, Piosson and normal distributions
12. Uses of variance stabilizing transformations.
13. Uses of Pearsonian $\chi 2$ distributions for large sample tests.

Suggested Reading:

1. Goon A.M., Gupta M.K.: Das Gupta.B. (2005), Fundamentals of Statistics, Vol. I, World Press, Calcutta.
2.Goon A.M., Gupta M.K.: Das Gupta.B. (2005), An Outline of Statistical Theory, Vol. I, World Press, Calcutta.
3. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2ndEdn. (Reprint) John Wiley and Sons.
4. Miller, I. and Miller, M. (2002) : John E. Freund's Mathematical Statistics (6th addition, low price edition), Prentice Hall of India.
5. Dudewicz, E. J., and Mishra, S. N. (1988): Modern Mathematical Statistics. John Wiley & Sons.
6. Mood A.M, Graybill F.A. and Boes D.C,: Introduction to the Theory of Statistics, McGraw Hill.
7. Bhat B.R, Srivenkatramana T and Rao Madhava K.S. (1997) Statistics: A Beginner's Text, Vol. I, New Age International (P) Ltd.
8. Snedecor G.W and Cochran W.G.(1967) Statistical Methods. lowa State University Press.

Paper: ST-M-5.2-T Survey Sampling and Official Statistics (Theoretical) Course Type: Major Credit 4 Marks 50

Unit 1

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, definition and procedure of selecting a sample, estimates of: population mean, total and proportion, variances of these estimates, estimates of their variances and sample size determination. (10L)

Unit 2

Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision, post stratification and its performance. Systematic Sampling: Technique, estimates of population mean and total, variances of these estimates (N=nxk). Comparison of systematic sampling with SRS and stratified sampling in the presence of linear trend and corrections. (10L)

Unit 3

Introduction to Ratio and regression methods of estimation, first approximation to the population mean and total (for SRS of large size), variances of these estimates and estimates of these variances, variances in terms of correlation coefficient for regression method of estimation and their comparison with SRS. Cluster sampling (equal clusters only) estimation of population mean and its variance, comparison (with and without randomly formed clusters). Relative efficiency of cluster sampling with SRS in terms of intra class correlation. Concept of subsampling. (12L)

Unit 4

Present official statistical system in India, Methods of collection of official statistics, their reliability and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), and National Statistical Commission. Government of India's Principal publications containing data on the topics such as population, industry and finance.

(12L)

Paper: ST-M-5.2-P Survey Sampling and Official Statistics (Practical) Course Type: Major Credit 2 Marks 25

List of Practical

1. To select a SRS with and without replacement.
2. For a population of size 5, estimation of population mean, population mean square and population variance. Enumeration of all possible samples of size 2 by WR and WOR and establish all properties relative to SRS.
3. For SRSWOR, estimation of mean, standard error, the sample size
4. Stratified Sampling: allocation of sample to strata by proportional and Neyman's methods Compare the efficiencies of above two methods relative to SRS
5. Estimation of gain in precision in stratified sampling.
6. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend.
7. Ratio and Regression estimation: Calculation of the population mean or total of the population. Calculation of mean squares. Comparison of the efficiencies of ratio and regression estimators relative to SRS.
8. Cluster sampling: estimation of mean or total, variance of the estimate, estimate of intra-class correlation coefficient, efficiency as compared to SRS.

Suggested Reading:

1. Cochran W.G. (1984): Sampling Techniques (3rd Ed.), Wiley Eastern.
2. Sukhatme,P.V., Sukhatme,B.V. Sukhatme,S. Asok,C.(1984). Sampling Theories of Survey With Application, IOWA State University Press and Indian Society of Agricultural Statistics
3. Murthy M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
4. Des Raj and Chandhok P. (1998): Sample Survey Theory, Narosa Publishing House.
5. Goon A.M., Gupta M.K. and Dasgupta B. (2001): Fundamentals of Statistics (Vol.2), World Press.
6. Guide to current Indian Official Statistics, Central Statistical Office, GOI, New Delhi.
7. WEBSITE http://mospi.nic.in/

Paper: ST-MI-5.1-T Applied Statistics (Theoretical) Course Type: Minor
Credit 3 Marks 35

Unit 1

Economic Time Series: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series. Measurement of trend by method of free-hand curve, method of semi-averages and method of least squares (linear, quadratic and modified exponential).Measurement of seasonal variations by method of ratio to trend. (10L)

Unit 2

Index numbers: Definition, Criteria for a good index number, different types of index numbers. Construction of index numbers of prices and quantities, consumer price index number. Uses and limitations of index numbers. (8L)

Unit 3

Statistical Quality Control: Importance of statistical methods in industrial research and practice. Determination of tolerance limits. Causes of variations in quality: chance and assignable. General theory of control charts, process & product control, Control charts for variables: X- bar and R-charts. Control charts for attributes: p and c-charts (8L)

Unit 4

Demographic Methods: Introduction, measurement of population, rates and ratios of vital events. Measurement of mortality: CDR, SDR (w.r.t. Age and sex), IMR, Standardized death rates. Life (mortality) tables: definition of its main functions and uses. Measurement of fertility and reproduction: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR. (8L)

Paper: ST-MI-5.1-P Applied Statistics (Practical) Course Type: Minor Credit 1 Marks 15

List of Practical:

1. Measurement of trend: Fitting of linear, quadratic trend, exponential curve and

plotting of trend values and comparing with given data graphically.
2. Measurement of seasonal indices by Ratio-to-trend method and plotting of trend values and comparing with given data graphically.
3. Construction of price and quantity index numbers by Laspeyre's formula, Paasche's formula, Marshall-Edgeworth's formula, Fisher's Formula. Comparison and interpretation.
4. Construction of wholesale price index number, fixed base index number and consumer price index number with interpretation
5. Construction and interpretation of X-bar & R-chart
6. Construction and interpretation p-chart (fixed sample size) and c-chart
7. Computation of measures of mortality
8. Completion of life table
9. Computation of measures of fertility and population growth

Suggested Reading:

1.Mukhopadhyay, P. (1999): Applied Statistics, New Central Book Agency, Calcutta. 2. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition World Press, Kolkata.
3. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals of Applied Statistics, 4th Edition (Reprint), Sultan Chand & Sons.
4. Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.

Paper: ST-MI-5.2-T Sampling Distribution (Theoretical) Course Type: Minor
Credit 4 Marks 50

Unit 1

Definitions of random sample, parameter and statistic, sampling distribution of a statistic, sampling distribution of sample mean, standard errors of sample mean, sample variance and sample proportion. (8L)

Unit 2

Exact sampling distribution: Definition of $\chi 2$ distribution with n degrees of freedom (d.f.), nature of p.d.f. curve for different degrees of freedom, mean, variance, m.g.f., mode, additive property. (8L)

Unit 3

Exact sampling distributions: Student's and Fishers t-distribution, their p.d.f., nature of probability curve with different degrees of freedom, mean, variance, moments and limiting form of t distribution. (8L)

Unit 4

Snedecore's F-distribution: its p.d.f., nature of p.d.f. curve with different degrees of freedom, mean, variance and mode. Distribution of $1/F(n_1,n_2)$. Relationship between t, F and $\chi 2$ distributions. Test of significance and confidence Intervals based on t and F distributions. (8L)

Suggested Reading:

1. Goon A.M., Gupta M.K.: Das Gupta.B. (2005), Fundamentals of Statistics, Vol. I, World Press, Calcutta.
2. Goon A.M., Gupta M.K.: Das Gupta.B. (2005), An Outline of Statistical Theory, Vol. I, World Press, Calcutta
3. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons.
4. Dudewicz, E. J., and Mishra, S. N. (1988): Modern Mathematical Statistics. JohnWiley & Sons.

YEAR 3: SEMESTER VI

Paper: ST-M-6.1-T Multivariate Analysis and Nonparametric Techniques (Theoretical)
Course Type: Major Credit 4 Marks 50

Unit 1
Bivariate Normal (BVN) distribution: p.d.f. of BVN, properties of BVN, marginal and conditional p.d.f. of BVN distribution.
Multivariate Data: Random Vector: Probability mass/density functions, Distribution function, Mean vector & Dispersion matrix, Marginal & Conditional distributions. (8L)

Unit 2
Multivariate Normal distribution and its properties. Sampling distribution for mean vector and variance-covariance matrix. Multiple and partial correlation coefficient and their properties. (10L)

Unit 3
Applications of Multivariate Analysis: Discriminant Analysis, Principal Components Analysis and Factor Analysis. (10L)

Unit 4
Nonparametric Tests: Introduction and Concept, Test for randomness based on total number of runs, Empirical distribution function, Kolmogrov Smirnov test for one sample, Sign tests- one sample and two samples, Wilcoxon-Mann-Whitney test, Kruskal-Wallis test. (12L)

Paper: ST-M-6.1-P Multivariate Analysis and Nonparametric Techniques (Practical)
Course Type: Major Credit 2 Marks 25

List of Practical
1. Multiple Correlation
2. Partial Correlation
3. Bivariate Normal Distribution,
4. Multivariate Normal Distribution
5. Discriminant Analysis

6. Principal Components Analysis
7. Factor Analysis
8. Test for randomness based on total number of runs,
9. Kolmogrov Smirnov test for one sample.
10. Sign test: one sample, two samples, large samples.
11. Wilcoxon-Mann-Whitney U-test
12. Kruskal-Wallis test

Suggested Reading:

1. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rdEdn., John Wiley
2. Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley.
3. Kshirsagar, A.M. (1972): Multivariate Analysis, 1stEdn. Marcel Dekker.
4. Johnson, R.A. and Wichern, D.W. (2007): Applied Multivariate Analysis, 6thEdn., Pearson & Prentice Hall
5. Mukhopadhyay, P.:Mathematical Statistics.
6. Gibbons, J. D. and Chakraborty, S (2003): Nonparametric Statistical Inference. 4th Ed.

Paper: ST-M-6.2-T Linear Models and Design of Experiments (Theoretical) Course Type: Major Credit 4 Marks 50

Linear Models

Unit 1

Gauss-Markov set-up: Theory of linear estimation, Estimability of linear parametric functions, Method of least squares, Gauss-Markov theorem, Estimation of error variance.
Regression analysis: Simple regression analysis, Estimation and hypothesis testing in case of simple and multiple regression models, Concept of model matrix and its use in estimation. (12L)

Unit 2

Analysis of variance: Definitions of fixed, random and mixed effect models, analysis of variance and covariance in one-way classified data for fixed effects models, analysis of variance and covariance in two-way classified data with one observation per cell for fixed effects models.
Model checking: Prediction from a fitted model, Violation of usual assumptions concerning normality, Homoscedasticity and collinearity, Diagnostics using quantile-quantile plots. (12L)

Design of Experiments

Unit 3

Experimental designs: Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks.
Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model and statistical analysis, relative efficiency, analysis with missing observations. (12L)

Unit 4

Incomplete Block Designs: Balanced Incomplete Block Design (BIBD) – parameters, relationships among its parameters, incidence matrix and its properties, Symmetric BIBD, Resolvable BIBD. (8L)

Unit 5

Factorial experiments: advantages, notations and concepts, 2^2, $2^3 \ldots 2^n$ and 3^2 factorial experiments, design and analysis, total and partial confounding for 2^n ($n \leq 5$) and 3^2 factorial experiments in a single replicate. (10L)

Paper: ST-M-6.2-P Linear Models and Design of Experiments (Practical)

Course Type: Major Credit 2 Marks 25

List of Practical

1. Estimability when X is a full rank matrix and not a full rank matrix
3. Simple Linear Regression
4. Multiple Regression
5. Tests for Linear Hypothesis
6. Analysis of Variance for one way classified data
7. Analysis of Variance for two way classified data with one observation per cell
8. Analysis of Covariance for one way and two way classified data
9. Analysis of a CRD, RBD and LSD
10. Intra Block analysis of a BIBD
11. Analysis of 2^2 and2^3 factorial designs in CRD and RBD
12. Analysis of a completely confounded two level factorial design in 2 blocks
13. Analysis of a partially confounded two level factorial design

Suggested Reading:

1. Renchner, A. C. And Schaalje, G. B. (2008). Linear Models in Statistics (Second edition), John Wiley and Sons.
2. Kshirsagar. Linear Models
3. Scheffe, H. Analysis of Variance. Wiley.
4. Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House.
5. Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd.
6. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8thEdn. World Press, Kolkata.
7. Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley.
8. Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.

Paper: ST-M-6.3-T Economic Statistics (Theoretical) Course Type: Major
Credit 4 Marks 50

Unit 1
Index numbers: Fixed-base and chain-base index numbers, tests for index numbers: time and factor reversal tests, circular test. Some important indices: consumer price index, wholesale price index – methods of construction and uses. (8L)

Unit 2
Introduction: Examples of time series from various fields, components of a times series, additive and multiplicative models. Trend and seasonal components: estimation of trend by linear filtering (simple and weighted moving averages) and curve fitting (polynomial, exponential and Gompertz), detrending, estimation of seasonal component by ratio-to-moving-average method, ratio to trend method, deseasonalization. (12L)

Unit 3
Stationary Time series: weak stationarity, autocorrelation function and correlogram. Some special Processes: moving-average (MA) process and autoregressive (AR) process of orders one and two, estimation of the parameters of AR(1) and AR(2) – Yule-Walker equations. Exponential smoothing, method of forecasting. (10L)

Unit 4
Theory and analysis of consumer demand: law of demand, price elasticity of demand, Engel curve – its different forms and properties, income elasticity of demand, estimation of Engel curves from family budget data by weighted least squares method. (10L)

Paper: ST-M-6.3-P Economic Statistics (Practical) Course Type: Major
Credit 2 Marks 25

List of Practical:

1. Calculation of price and quantity index numbers using simple and weighted average of price relatives.
2. To calculate the Chain Base index numbers.
3. To calculate consumer price index number.
4. Fitting of trend by moving average and mathematical curve fitting method.
5. Determination of seasonal indices.
6. Exponential smoothing
7. Computation of income elasticity of demand from family budget data.
8. Estimation of Engel curve.

Suggested Reading:
1. Gun, A. M., Gupta, M. K. & Dasgupta, B.: Fundamentals of Statistics vol II, World Press.
2. Mukhopadhyay, P.: Applied Statistics.
3. Prais & Houthakker: Analysis of Family Budget Data.
4. Kendall. M. G. & Stuart, A.: The Advanced Theory of Statistics, Vol III, Charles Griffin.