SEMESTER POST - GRADUATE COURSE

IN

STATISTICS

Deparatment of Statistics, H.N.B.Garhwal Central University, Srinagar (Garhwal)

M.A. / M.Sc. course in Statistics is meant for two years spread in four semesters. Each of the theory and practical paper consists of 100 marks. Four theory papers and two practicals will be undertaken in each semester.

Eligibility: B.A. /B.Sc. with Mathematics. Preference to those who have Statistics as a subject at B.A. /B.Sc. level.

(Revised in 2018)

Distribution of different courses and credits in various semesters:

First Semester

Course Code	Title of the Paper	Credit
ST-101	Real Analysis and Complex Analysis	**3**
ST-102	Matrices	**3**
ST-103	Measure Theory and Probability	**3**
ST-104	Distribution Theory	**3**
SP-105	Practical I	**3**
SP-106	Practical II	**3**
	Total	**18**

Second Semester

Course Code	Title of the Paper	Credit
ST-201	Statistical Inference	**3**
ST-202	Survey Sampling	**3**
ST-203	Design and Analysis of Experiment	**3**
ST-204	Linear Algebra	**3**
SP-205	Practical I	**3**
SP-206	Practical II	**3**
	Total	**18**

Third Semester

Course Code	Title of the Paper	Credit
ST-301	Multivariate Analysis and Curve Fitting	**3**
Elective/Optional Papers	**Any three papers out of the paper Nos. ST-302 to ST-309**	**3 X 3= 9**
ST-302	Advanced Operations Research I	
ST-303	Statistical process and Quality control	
ST-304	Reliability theory	
ST-305	Research methodology and project work - I	

ST-306	Statistical decision theory	
ST-307	Statistical Computing	
ST-308	Nonparametric and Semiparametric methods	
ST-309	Linear Models and Regression Analysis	
ST-310	Time series analysis	
SP-311	Practical I	**3**
SP-312	Practical II	**3**
	Total	**18**

Fourth Semester

Course Code	**Title of the Paper**	**Credit**
ST-401	Economic Statistics and Demography	**3**
Elective/Optional Papers	**Any three papers out of the paper Nos. ST-402 to ST-407**	**3 X 3= 9**
ST-402	Advanced Operations Research II	
ST-403	Bio Statistics	
ST-404	Stochastic Process	
ST-405	Official Statistics	
ST-406	Bayesian Inference	
ST-407	Econometrics	
ST-408	Environment Statistics	
ST-409	Project Work	
SP-410	Practical I	**3**
SP-411	Practical II	**3**
	Total	**18**
	Grand Total	**72**

First Semester

Course No. ST-101 **Title: Real Analysis and Complex Analysis**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Monotone functions and functions of bounded variation. Absolute continuity of functions, standard properties. Uniform convergence of sequence of functions and series of functions. Cauchy's criterion and Weirstrass M-test. Condititions for termwise differentiation and termwise integration (statements only). Power series and radius of convergence.

Riemann-Stieltjes integration. Statement of the standard properties and problems based on them. Multiple integrals and their evaluation by repeated integration. Change of variable in multiple integration. Beta and gamma functions. Differentiation under integral sign. Leibnitz rule. Dirichlet integral, Liouville's extension.

Maxima-minima of functions of several variables, Constrained maxima-minima of functions.

Analytic function, Cauchy-Riemann equations. Statement of Cauchy theorem and of Cauchy integral formula with applications,Taylor's series. Singularities, Laurent series. Residue and contour integration.

Fourier and Laplace transforms.

Books Recommended:

1. Apostol, T.M. (1975). Mathematical Analysis, Addison- Wesley.
2. Bartle, R.G. (1976). Elements of Real Analysis, John Wiley & Sons.
3. Berbarian, S.K. (1998). Fundamentals of Real Analysis, Springer-Verlag.
4. Conway, J.B. (1978). Functions of one Complex Variable, Springer-Verlag.
5. Priestley, H.A. (1985). Complex Analysis, Clarenton Press Oxford.
6. Rudin, W. (1985). Principles of Mathematical Analysis, McGraw Hill.

Course No. ST-102 **Title: Matrices**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Different type of matrices, algebra of matrices, row and column spaces of a matrix, elementary matrices, determinant, singular and non-singular matrices, adjoint of matrix, rank and inverse of matrix, portioned matrices and Kroneker product.

Canonical form, Hermit canonical form, diagonal form, triangular form, Jordan form, quadratic form, generalized inverse, Moore-Penrose generalized inverse, idempotent matrices.

Characteristic roots and vectors, algebraic multiplicity of characteristic roots, Caley-Hamilton theorem, spectral decomposition of real symmetric matrix.

Positive, semi positive , negative and semi negative definite matrices, similar matrices

Derivative of determinant.

Books Recommended:

1. Biswas, S, (1984): Topics in Algebra of matrices, Academic Publications.
2. Shanti Narain: A text books of matrices, S. Chand and Company (Pvt) Ltd.
3. Frank Ayres , JR: Schaum's outline series Theory and problems.

Course No. ST-103 **Title: Measure Theory and Probability**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Measure and integration: Classes of sets, field, sigma fields, minimal sigma fields, Borel sigma fields, Limsup and liminf of a sets, Measure, Probability measure, properties of a measure, Lebesgue and Lebesgue- Steljes measures, measurable functions.

Probability : Baye's theorem. Random variable. Marginal and conditional distributions, Expectation. Tehebycheffs inequality and improvements on it, convergence in probability. The weak law of large numbers Bernoulli's theorem. Convergence in distribution continuity theorem. Khinchin's theorem. Strong law of large numbers Kologorov's theorem, Borel zero-one law, Borel-Cantelli lemma.

Central limit theorem-Lindberg Levy's and liapouneff forms.

Books Recommended:

1. Goon Gupta and Das Gupta: An outline of Statistical theory, World Press Calcutta, Vol. 1.

2. Rohtagi, V.K. and Saleh A.K. (2005): Probability Theory, John Wiley.
3. B.R. Bhat(1985): Modern Probability Theory.
4. Basu, A.K. (2001): Probability and Measure theory, Narosa Pub.

Course No. ST-104 **Title: Distribution Theory**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Univariate Discrete distributions; properties and applications of Uniform Discrete, Binomial, Poisson, Hypergeometric, Geometric Negative Binomial distribution and Multinomial distribution.

Univariate continuous Distribution; statement, derivation of properties and applications of Normal, Beta, Gamma, Cauchy, Exponential

Sampling distribution from Binomial, Poisson, Exponential and Normal populations, Bivariate distributions; bivariate normal. Distribution of functions of random variables.

Large sample tests. Derivation and properties of chi-square, t and F distribution and their inter relationship. Test of significance based on chi-square, t and F distribution.

Order statistics, their distributions and properties, joint and marginal distributions of order statistics, extreme values and their asymptotic distributions (statement only) with applications.

Books Recommended:

1. Rao, C.R. (1973): Linear Statistical Inference and its Application, Wiley Eastern.
2. Kendall, M.G., Stuart, A: The Advanced Theory of Statistics: Distribution Theory. Vol. 1.
3. Johnson and Kotz: Continuous Univariate Distribution, Vol. 1 and Vol. 2, Wiley.
4. Dudwvicz, E.J. and Mishra, S.N. (1988): Modern Mathematics Statistics, Wiley. International students edition.

Course No. SP-105 **Title: Practical I**

Credit: 3 **Maximum Marks: 100**

Syllabus: Practicals based on ST-102 and ST-103.

(Practical paper will be of 100 marks out of which 20 marks will be assigned on sessionals / tutorial / class tests / seminars in class / group discussions and 80 marks will be assigned on the end semester examination out of which 60 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva-voce).

Course No. SP-106 **Title: Practical II**

Credit: 3 **Maximum Marks: 100**

Syllabus: Practicals based on ST-104.

(Practical paper will be of 100 marks out of which 20 marks will be assigned on sessionals / tutorial / class tests / seminars in class / group discussions and 80 marks will be assigned on the end semester examination out of which 60 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva-voce).

Second Semester

Course No. ST-201 **Title: Statistical Inference**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Problem of point estimation: Unbiasedness, Consistency, Sufficiency, Efficiency, Complete statistics, Complete Sufficient statistics. Factorization theorem, Exponential family of distributions and its properties, Minimum-variance unbiased estimators, Rao Blackwell theorem. Lehmann Schefe's theorm, Cramer-Rao Inequality.

Method of estimation- Method of Maximum Likelihood and its properties.

Interval estimation, Interval Estimation: Confidence Region, shortest confidence intervals, General method of finding confidence interval. Method of obtaining confidence intervals based on small and large samples, Relationship with the testing of hypothesis.

Testing of hypothesis: Basic concept, Simple and composite hypothesis, Two types of error, power of the test , Neyman-Pearson lemma and its generalization, Types A, A1 critical regions, Construction of most powerful test, Uniformly most powerful tests, Uniformly most powerful Unbiased test using N P lemma, likelihood ratio test and its properties.

General decision problem: Basic concept of loss function, risk function, Minimax and Bays rule.

Books Recommended:

1. Lehmann, E.L.(1986): Theory of Point Estimation, Student Edition.
2. Zacks, S. (1971): Theory of Statistical Inference, Wiley, New York.
3. Rao, C.R. (1973): Linear Statistical Inference and its applications, 2nd edition, John wiley and sons.
4. Kale, B.K. (1999): A First course on Parametric Inference, Narosa Publishing House.
5. Goon, A.M., M.K. Gupta, & B. Das Gupta: Outline of Statistics, Vol-II.

Course No. ST-202 **Title: Survey Sampling**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Basic Principles: Census and sample surveys, advantages and disadvantages of sample surveys. Basic principles in sampling, survey enquiries, choice of sampling units, problems of sample size, Bias in selection and estimation, simple random sampling, sampling from finite populations with and without replacement, sampling of attributes, unbiased estimates of population total, mean and estimation of their variances.

Stratified Sampling: Reason for stratification, choice of strata, choice of sampling unit, stratified random sampling, estimation of population mean and its variance, choice of sample sizes in different strata, variances of estimates with different allocation, effects of deviation from optimum allocation, estimation of the gain in precision due to stratification, cost function, construction of strata.

Systematic Sampling: Estimation of sample mean and its variance, comparison of systematic sampling with simple random and stratified sampling.

Ratio and Regression Estimation: Ratio and regression methods of estimation, variances of the estimates, optimum property of ratio estimates, comparison among ratio and regression and simple and biased estimates.

Cluster Sampling: Estimates of mean and its variance for equal and unequal clusters, efficiency in terms of intra-class correlation, optimum unit of sampling, sampling with replacement, estimation of mean and variance.

Double Sampling: Multistage sampling with special reference to two stage design, Non-sampling errors, problems of non response, errors of measurements, Interpenetrating sub sampling. Randomized response techniques. Pilot survey.

PPS Sampling schemes, sampling techniques with varying probabilities for simple random sampling. Herwits Thompson Estimators, Mid Zuno Sen Sampling Scheme.

Books Recommended:

1. Cochran W.G.: Sampling Techniques, Wiley Eastern Ltd., New Delhi.
2. Des Raj and Chandhok (1998): Sampling Theory, Narosa Publishing House.
3. Mukhopadhayay Parimal: Theory and Methods of Survey Sampling-Prentice Hall of India Ltd.
4. Kish L: Survey Sampling.

Course No. ST-203 **Title: Design and Analysis of Experiment**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Analysis of Variance for one-way, two-way with one/m observation per cell for fixed, mixed and random effects models, Tuckey's test for non- additivity. General theory of analysis of experimental designs; completely randomized design, Randomized block design and Latin square design, Missing plot techniques in RBD and LSD.

Analysis of covariance for CRD and RBD. Split plot and strip plot designs. Complete and Partial confounding. General factorial experiments: Definition, Estimation of factor's effect. Analysis of the factorial experiments using CRD and RBD.

Balanced Incomplete Block Designs: Balanced Incomplete Block Design with and without recovery of inter information.

Books Recommended:

1. Goon A.M., Gupta, M.K. and Das Gupta, B.: Outline of Statistics Vol.-2.
2. Das and Giri: Design and analysis of experiment.
3. Cochran, W.G. and Cox, G.M. (1959): Experimental Designs, Asia Publishing House, Singapore.
4. Mann H.B.: Analysis and Design of Experiments, Dover Publications Inc. New York.

Course No. ST-204 **Title: Linear Algebra**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Vector Space, subspace, linear dependence and independence, maximal linearly independent subset, basis and dimension of vector space, finite dimensional vector spaces, Example of vector spaces over real and complex variable.

Linear transformation, algebra of linear transformation, null space and ranges, rank and nullity of linear transformation, Rank nullity theorem, Eigenvalues and eigenvectors for Linear Transformations, matrix representation of linear transformation.

Vector spaces with an inner product, Gram-Schmidt orthogonalization process, orthonormal projection of a vector.

Books Recommended:

1. Biswas, S, (1984): Topics in Algebra of matrices, Academic Publications.
2. Shanti Narain: A text books of matrices, S. Chand and Company (Pvt) Ltd.
3. Stephen H. Friedberg, Arnold J. Insel Lawrence E. Spence: Liner Algebra, Pearson Education Limited.
4. Kenneth Hoffman and Ray Kunje:Linear Algebra, Prentice-Hall Inc.

Course No. SP-205 **Title: Practical I**

Credit: 3 **Maximum Marks: 100**

Syllabus: Practicals based on ST-202.

(Practical paper will be of 100 marks out of which 20 marks will be assigned on sessionals / tutorial / class tests / seminars in class / group discussions and 80 marks will be assigned on the end semester examination out of which 60 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva-voce).

Course No. SP-206 **Title: Practical II**

Credit: 3 **Maximum Marks: 100**

Syllabus: Practicals based on ST-203.

(Practical paper will be of 100 marks out of which 20 marks will be assigned on sessionals / tutorial / class tests / seminars in class / group discussions and 80 marks will be assigned on the end semester examination out of which 60 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva-voce).

Third Semester

Course No. ST-301 **Title: Multivariate Analysis and Curve Fitting**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Multivariate normal distribution and its properties. Random sampling from multivariate normal distribution. Maximum likelihood estimators of parameters, distribution of sample mean vector.

Wishart matrix- its distribution and properties, distribution of sample generalized variance, null and non-null distribution of multiple correlation coefficient.

Hotelling's T^2 and its sampling distribution, application in test on mean vector for one and more multivariate normal population.

Classification and discrimination procedures for discrimination between two multivariate normal populations-sample discriminant function, test associated with discriminant functions, probabilities of misclassification and their estimation, classification into more than two multivariate normal populations, Fisher Behren Problem.

Mahalonobis D^2 Statistics and its application, Principal component, Canonical variables and canonical correlations: definition, use, estimation and computation.

Books Recommended:

1. Anderson, T.W. (1983): An Introduction to Multivariate Statistical Analysis, 2nd Ed., Wiley.
2. N.S. Giri: Multivariate Statistical Analysis.
3. Johnson, R. and Wychern(1992): Applied Multivariate Statistical Analysis, Prentice Hall, 3rd Edition.
4. Sharma, S. (1996): Applied Multivariate Techniques, Wiley.

Elective/Optional papers: Any Three papers out of the Following:

Course No. ST-302 **Title: Advanced Operations Research I**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Definition and scope of Operational research; phases in Operations Research; models and their solutions.

Review of linear programming problems (LPP); revised simplex method; duality theorem. Two-person games; pure and mixed strategies; existence of solution and uniqueness of value in zero-sum games; finding solution in 2x2, 2xm and mxn games; reduction of game problem to a linear programming problem.

Allocation Problems: transportation problem (TP); degeneracy in TP; unbalanced TP, Assignment Problem.

Dynamic Programming: Bellman's principle of optimality; general formulation of dynamic programming; computational methods and applications of dynamic programming.

Queuing Models: Steady-state solutions of (M/M/1) and (M/M/C) models with associated distributions of queue length and waiting time; M/G/1.

Non-Linear Programming: Kuhn-Tucker conditions; Wolfe's and Beale's algorithms for solving quadratic programming problems.

Inventory Control- Economic lot Size, Formulae of Harris for known demand and its extension allowing shortage, Random demand: Discrete and Continuous case.

Books Recommended:

1. Sharma, S.D.: Operation Research, Pragati Prakashan, Meerut.
2. Taha, H.A. (1982): Operations Research: An Introduction; MacMillan Publishing Company, New York.
3. Kanti Swaroop, Gupta, P.K. and Singh, M.M. (1985): Operations Research; Sultan Chand and Sons.
4. Hadley, G and Whitin, T.M. (1963): Analysis of Inventory System; Prentice Hall.

Course No. ST-303 **Title: Statistical Process and Quality Control**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Basic concept of process monitoring and control, process capability and process optimization.

General theory and review of control charts for attribute and variable data; O.C. and A.R.L. of control charts; control by gauging; Moving average and exponentially weighted

moving average charts; Cu-sum charts using V-masks and decision intervals; Economic design of X-bar chart.

Acceptance sampling plans for attribute inspection; single, double and sequential sampling plans and their properties; Plans for inspection by variables for one-sided and two-sided specifications; Mil Std and IS plans; continuous sampling plans of Doge type abd Wald-Wolfiwitz type and their properties. Bayesian sampling plans.

Capability indices Cp, Cpk and Cpm; estimation, confidence intervals and tests of hypotheses relating to capability indices for Normally distributed characteristics.

Use of Design of Experiments in SPC; factorial experiments, fractional factorial designs, construction of such designs and analysis of data.

Multivariate quality control; use of control ellipsoid and of utility function.

Books Recommended:

1. Montgomery, D.C. (1985): Introduction to Statistical Quality Control; Wiley.
2. Wetherill, G.B. and Brown, D.W.: Statistical Process Control: Theory and Practice; Chapman and Hall.
3. Phadke, M.S.(1989): Quality Engineering Through Robust Design, Prentice Hall.
4. Ott, E.R. (1975): Process Quality Control; McGraw Hill.

Course No. ST-304 **Title: Reliability theory**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Reliability concepts and measures; components and systems; coherent systems; Reliability of coherent system; cuts and paths; modular decomposition; bounds on system reliability; structural and reliability importance of components.

Life distribution; reliability function, hazard rate; common life distribution- exponential, Weibull, gamma, normal, etc.; Estimation of parameters and tests in these models.

Notion of aging; IFR; IFRA; NBU; DMRL and NBUE classes and their duals; Io of memory property of the exponential distribution; closures of these classes under formation of coherent system; convolution and mixture.

Basic ideas of accelerated life testing.

Univariate shock models and life distribution arising out of them; bivariate shock models; common bivariate exponential distributions and their properties. Reliability estsimation based on failure times in variously censored life tests and in tests with replacement of failed items; stress-strength reliability and its estimation.

Books Recommended:

1. Zacks, S.: Reliability Theory, Springer.
2. Barlow, R.E. and Proschan, F. (1985): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
3. Nelson, W. (1982): Applied life Data Analysis; John Wiley.
4. Lawless, J.F. (1982): Statistical Models and Methods of Life Time Data; John Wiley.

Course No. ST-305 **Title: Research Methodology and Project Work – I**

Credit: 3

Maximum Marks: 100
(a) Semester Examination: 60
(b) Preparation of project proposal, discussion and presentation: 40

Meaning of Research – Objective of Research – Approach to research – significance of research – type of research – research in Social Sciences – facts, theories and concepts in Social Science research – research design – features of a good research design.

Research problem – Identifying the research problem – formulation of research problem-concept of hypothesis – role and formulation of hypothesis – scientific method of research – nature of scientific research – stages of scientific method.

Logic and scientific method – Deductive and inductive methods – the Case study method-merits and demerits of Case study methods – survey methods – merits and demerits of survey methods – types of survey – selecting the survey method – sample surveys – different types – merits and demerits.

Schedule and questionnaire – Principle underlying the construction of questionnaire-measurement and scaling techniques – processing and analysis of data.

Interpretation and report writing – Steps – bibliography, quality of a good research report.

Books Recommended:

1. Kothari, C.R. (1985): Research Methodology: Methods and Techniques, Wiley Eastern.
2. Dominowski, R.L. (1980): Research Methods, Prentice Hall Inc., New Jersey.
3. Mishra, R.P. (1980): Research Methodology, Handbook Concept Publishing Company, New Delhi.
4. IIPS (1996): Research Methodology, IIPS, Mumbai.

Course No. ST-306 **Title: Statistical decision theory**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Decision problem and 2-person game, utility theory, loss functions, expected loss, decision rules(non-randomized and randomized), decision principles (conditional Bayes, frequentist), inference problems as decision problems optimal decision rules, concepts of admissibility and completeness, Bayes rules, admissibility of Bayes rules, Supporting and separating hyperplane theorems.

Minimax theorem for finite parameter space, minimax estimators of Normal and Poisson means, admissibility of minimax rules, Invariant decision rules-location parameter problems, invariance and minimaxity, admissibility of invariant rules.

Complete class theorem, complete and essentially complete classes in simple estimation and testing situations, estimation of a distribution function, Multivariate normal distribution, Exponential family of distributions.

Sufficient statistics, essentially complete classes of rules based on sufficient statistics, complete sufficient statistics, sequential decision rules, Bayes and minimax sequential decision rules, invariant sequential decision problems, sequential tests of a simple hypothesis against a simple alterative, SPRT and stopping rule principle.

Books Recommended:

1. Berger, J.O. (1985): Statistical Decision Theory and Bayesian Analysis, 2nd Edition. Springer Verlag.
2. Rohatgi, V.K. (1988): An Introduction to Probability and Mathematical Statistics, Wiley Eastern, New Delhi.
3. Rao, C.R. (1973): Linear Statistical Inference and its Applications, Wiley Eastern.
4. Ferguson, T.S.(1967): Mathematical Statistics-A Decision Theoretic Approach, Academic Pres.

Course No. ST-307 **Title: Statistical computing**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Computer organization, problem analysis, Algorithm development, Flow chart, Introduction to Fortran 77, Data type, operators and expressions, Assignment statement, Arithmetic and logical operation, List directed and Format-directed Input / Output statement**.**

Windows: Use of windows, its operations and applications. MS word: operations of MS word and applications.

MS excel: Use of MS excel, its operations, solution of statistical problems using MS excel.

MATLAB/MINITAB: Use of MATLAB/MINITAB, computation of statistical problem using MATLAB/MINITAB.

A statistical package such as SPSS or R.

Books Recommended:

1. B. Ryan and B.L. Joiner (2001): Minitab handbook, 4th edition, Duxbury.
2. R.A. Thisted (1988): Elements of statistical computing, Chapman and hall.
3. Ram Kumar: Introduction to Fortran-77.
4. V.Raja Ramen: Fortran-77.

Course No. ST-308 **Title: Nonparametric and Semiparametric methods**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Empirical distribution function, Glivenko Cantelli Theorem, Kolmogorov Goodness of fit test.

One sample U-statistics, Kernel and symmetric kernel, Two sample U-statistics, Asymptotic distribution of U-statistics. UMVUE property of U-statistics, Asymptotic distribution of linear function of order statistics.

Rank tests, Locally most powerful rank tests, Linear rank statistics and their distributional properties under null hypothesis, Pitman's asymptotic relative efficiency.

One sample location problem, sign test and signed rank test, two sample Kolmogorov Smirnov tests. Two sample location and scale problems. Wilcoxon-Mann-Whitney test, normal score test, ARE of various tests based on linear rank statistics. Kruskal-Wallis K sample test.

Cox's Proportional Hazard Model, rank test (partial likelihood) for regression coefficients. Concepts of jackknifing method of Quenouille for reducing bias, Bootstrap methods, Confidence intervals.

Books recommended:

1. Davison, A.C. and Hinkley, D.V. (1997): Bootstrap methods and their application, Cambridge University Press.
2. Gibbons, J.D. (1985): Nonparametric statistical inference, 2nd ed., Marcel Dekker, Inc.
3. Randles, R.H. and Wolfe, D.A. (1979): Introduction to the theory of nonparametric statistics, John Wiley & Sons, Inc.
4. Puri, M.L. and Sen, P.K. (1971): Nonparametric methods in multivariate analysis, John Wiley & Sons, Inc.

Course No. ST-309 **Title: Linear Models and Regression Analysis**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Standard Gauss-Markov models: Estimability of parameters, Best linear unbiased estimator (BLUE), method of least square and Gauss-Markov theorem, Variance and Covariance of BLUE.

Introducing of one way random effects linear models and estimation of Variance components.

Maximum likelihood, MINQUE and restricted maximum likelihood estimators of variance components, best linear unbiased predicators (BLUP).

Bi-variate and multiple linear regression, polynomial regression, use of orthogonal polynomial. Linear and non-linear regression models.

Books Recommended:

1. Rao, C.R. and Kleffe, J. (1988). Estimation of variance component and applications, North Holland.
2. Chatterjee, S. and Prince, B. (1991): Regression Analysis by example, John Wiley, New York.
3. Draper, N.R. and Smith H. (1998): Applied Regression Analysis, 3rd Ed. Wiley.
4. Cook, R.D. and Weisherg, S. (1982): Residuals and Inference in Regression, Chapman and Hall.

Course No. ST-310 **Title: Time series analysis**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Time-Series as discrete parameter stochastic process. Auto covariance and autocorrelation function and their properties. Exploratory time series analysis, Holt and winters smoothing. Forecasting based on smoothing, adaptive smoothing.

Detailed study of the stationary processes; (1) moving average(MA), (2) auto regressive(AR), (3) ARMA and (4) AR integrated MA(ARIMA) models. Box-Jenkin models.

Discussion(without proof) of estimation of mean, auto covariance and autocorrelation function under large sample theory. Choice of AR and MA periods. Estimation of ARIMA model parameters, Forecasting.

Spectral analysis of weakly stationary process. Periodogram and correlogram analysis. Computations based on Fourier transform.

Spectral decomposition of weakly AR process and representation as a one- sided MA process- necessary and sufficient condition. Implication in prediction problems.

Books recommended:

1. Anderson, T.W. (1971): The Statistical Analysis of Time Series, John Wiley, New York.
2. Box, G.E.P. and Jenkins, G.M. (1976): Time Series Analysis-Forecasting and Control, Holden-day, San Francisco.
3. Kendall, Sir Maurice and Ord, J.K. (1990): Time Series, Edward Arnold, London.
4. Findley, D.F. (Ed.) (1981): Applied Time Series II, Academic Press.

Course No. SP-311 **Title: Practical I**

Credit: 3 **Maximum Marks: 100**

Syllabus: Practicals based on ST-301.

(Practical paper will be of 100 marks out of which 20 marks will be assigned on sessionals / tutorial / class tests / seminars in class / group discussions and 80 marks will be assigned on the end semester examination out of which 60 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva-voce).

Course No. SP-312 **Title: Practical II**

Credit: 3 **Maximum Marks: 100**

Syllabus: Practicals based on selected elective papers.

(Practical paper will be of 100 marks out of which 20 marks will be assigned on sessionals / tutorial / class tests / seminars in class / group discussions and 80 marks will be assigned on the end semester examination out of which 60 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva-voce).

Fourth Semester

Course No. ST-401 **Title: Economic Statistics and Demography**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Time Series Analysis: Objects, Decomposition, Tests of Randomness, Trend component, polynomial, logistic, Gompertz, Log-normal trend functions, smoothing of moving average, Spencer's formulae and effects, Slutsky-yule effect, variate difference method, Measurement of seasonal and cyclic functions, peridogram and Harmonic analysis, Autocorrelation and Correlogram analysis.

Demand Analysis: Distribution of Income, Income and Demand elasticities. Methods for estimating elasticities using family budget data and time series data, Engel's Curve and Engel's law, Pareto's Analysis.

Demography: Source of Demographic data, Limitations and uses of demographic data, vital rates and ratios, Definition, construction and uses, life tables, complete and abridged construction of life table from vital statistics, uses of life tables. Logistic and other population growth curves. Measure of fertility gross and net reproduction rates, stationary and stable population theory. Uses of Lotka's stable population theory in estimation of demographic parameters, methods of inter-censal and post-censal estimation.

Books Recommended:

1. Lodge, II. F & Roming: Sampling Inspection Plans and Tables, John Wiley
2. Goon Gupta and Das Gupta: Fundamental of Statistics, Vol-II, The World Press, Pvt. Ltd.
3. Biswas, S: Stochastic processes in demography and applications
4. Johnsonton J: Economic Models, John Wiley and Sons, New York.

Elective/Optional papers: Any Three papers out of the Following:

Course No. ST-402 **Title: Advanced Operations Research II**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Integer Programming: Branch and bound algorithm and cutting plane algorithm. Multi-criterion and goal programming.

Stochastic Programming; quantile rules.

Two-stage programming; use of fractional programming.

Sequencing and scheduling problems: 2 machines n-job and 3-machines n-job problems with identical machine sequence for all jobs; 2-job n-machine problem with different routing; branch and bound method for solving travelling-salesman problems.

Sensitivity analysis. Parametric programming.

Project management: CPM and PERT; probability of project completion; PERT-crashing.

Replacement problems: block and age replacement policies; dynamic programming approach for maintenance problems; replacement of items with long life.

Transient solution of M/M/1 queue; bulk queues(bulk arrival and bulk service); finite queues; queues in tandem; GI/G/1 queue and its solutions; simulation of queues.

Books Recommended:

1. Taha, H.A. (1982): Operations Research: An Introduction; MacMillan Publishing Company, New York.
2. Shamblin, J.E. and Stevens, G.T. (1974): Operations Research: A Fundamental Approach; McGraw Hill.
3. Kanti Swaroop, Gupta, P.K. and Singh, M.M. (1985): Operations Research; Sultan Chand and Sons.
4. Kleinrock, L. (1975): Queuing Systems, Vol. I; John Wiley.
5. Starr, M.K. and Miller, D.W. (1962): Inventory Control-Theory and Practice; Prentice Hall.

Course No. ST-403 **Title: Bio Statistics**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Type of biological assays: direct assays, indirect assays, parallel line assays. Incomplete block designs for bio assays.

Response surfaces: Linear Response surface designs, second order response surface designs, variance of estimated response.

Introduction to clinical trials: the need of clinical trials, bias and random error in clinical studies, overview of phase 1-4 trials. Analysis of categorical outcomes from phase I-III Trials, analysis of survival data from clinical trials.

Analysis of One DNA sequence: Shotgun Sequencing, Modeling signals in DNA.

Analysis of multiple DNA or Protein Sequences: Alignment Algorithms for Two sequences, Protein sequences and Substitution Matrices.

Books Recommended:

1. Z. Govindarajulu(2000): Statistical technique in Bioassay, S. Kargar.
2. 2. Das, M.N. and Giri, N. (1975): Design and Analysis of experiments, New age international.
3. S. Piantadosi (1997): Clinical trials. A methodological perspective. Wiley & sons.
4. J.L. Fleiss (1989): The design and analysis of clinical experiments, Wiley & sons.

Course No. ST-404 **Title: Stochastic Process**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Probability generating function, Binomial, Poisson, Geometric and Negative Binomial. Convolution. General Stochastic Process, Definition, classification and examples. Compound distribution.

Branching process, Properties of Generating function, Probability of extinction, Distribution of total progeny. Random walk, first passage time, Gambler's ruin problem, duration of game.

Markov chains, higher transition probabilities. Classifications of states and chain, determination of higher transition probabilities. Stability of Markov system, limiting behavior.

Poisson process and related distribution. Generalization of Poisson process. Birth process, Yule-Furry process, Generalized Birth death processes, Linear Birth death processes.

Books Recommended:

1. Medhi, J. (1982): Stochastic process, New age international, New Delhi.
2. Bhat, B.R.: Stochastic models, Analysis and applications
3. Ross, S.M.: Stochastic process, New age international, New Delhi.
4. Bailey, N.T.J.: Elements of Stochastic process.

Course No. ST-405 **Title: Official Statistics**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Introduction to Indian and International Statistical systems. Present Official Statistical System in India, role, functions and activates of central and state organization. Organization of large scale sample surveys methods of collection of official statistics, Role of National Sample Survey Organization.

General and special data dissemination systems, population growth in developed and developing countries. Evaluation of performance of family welfare programs projection of labor force and manpower. Scope and content of population of census of India.

System of collection of agriculture Statistics, Crop forecasting and estimation. Support prices buffer stock, impact of irrigation projects.

Statistics related to industries, balance of payment, cost of living, educational and other Social Statistics.

Books Recommended:

1. Basic Statistics relating to Indian Economy (CSO) 1990.
2. Statistical system in India (CSO) 1975.
3. Guide to Official Statistics (CSO) 1999.
4. Principles and accommodation of National Populations Census. UNESCO.

Course No. ST-406 **Title: Bayesian Inference**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Subjective probability, its existence and interpretation. Prior distribution, subjective determination of prior distribution. Improper priors, non-informative (default) priors, invariant priors. Conjugate prior families, construction of conjugate families using sufficient statistics of fixed dimension, mixtures of conjugate priors, hierarchical priors and partial exchangeability. Parametric Empirical Bayes.

Bayesian inference: Bayes sufficiency, summary through posterior, predictive inference.

Bayesian decision theory: Bayes solutions for practical decision problems. Point estimation, credible sets, testing of hypotheses. Comparison with classical procedures. Admissibility and minimaxity of Bayes and generalized Bayes procedures.

Ideas on Bayesian robustness. Asymptotic expansion for the posterior density. Bayesian calculation, Monte-Carlo Integration and Markov chain. Monte Carlo techniques (Without proof).

Books Recommended:

1. Berger, J.O.: Statistical Decision Theory and Bayesian analysis, Springer Verlag.
2. Robert, C.P. and Casella, G.: Monte Carlo Statistical Methods, Springer Verlag.
3. Leonard, T. and Hsu, J.S.J.: Bayesian Methods, Cambridge University Press.
4. Box, G.P. and Tiao, G.C.: Bayesian Inference in Statistical Analysis, Addison-Wesley.

Course No. ST-407 **Title: Econometrics**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Nature of econometrics, The general linear model (GLM) and its extensions, Use of dummy variables and seasonal adjustment, Generalized least squares (GLS) estimation and prediction, Heteroscedastic disturbances, Pure and mixed estimation, Grouping of observations and of equations.

Auto correlation, its consequences and tests, Theil BLUS procedure: estimation and prediction, Multicollinearity problem, its implications and tools for handling the problem, Ridge regression.

Linear regression with stochastic regressors, Instrumental variable estimation, Errors in variables, Autoregressive linear regression, Distributed lag models, Simultaneous linear equations model, Examples, Identification problem, Restrictions on structural parameters - rank and order conditions, Restrictions on variances and covariances.

Estimation in simultaneous equations model, Recursive systems, 2 SLS Estimators. Limited information estimators, k - class estimators. 3 SLS estimation, Full information maximum likelihood method.

Books Recommended:

1. Johnston, J. (1984): Econometrics methods, Third Edition, McGraw Hill.
2. Apte, P.G. (1990): Text books of Econometrics, Tata McGraw Hill.
3. Damodar N. Gujrati(2004): Basic Econometrics, Fourth edition, McGraw Hill.
4. Cramer, J.S. (1971): Empirical Econometrics, North Holland.

Course No. ST-408 **Title: Environment Statistics**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Ecological diversity: species abundance curve, Indices of diversity (Simpson's Index, Shannon-Wiener index). Diversity as average rarity. Harvesting renewable biological resources-Maximum sustainable yield, tragedy of the commons, Air and water pollution.

Books Recommended:

1. Bodkin, Daniel D.(1995): Environmental Science-Earth as a living planet, John Wiley & Sons, New York
2. Clack, C.W.(1976): Mathematical Bioeconomics: Optimal management of renewable resources, John Wiley and Sons, New York
3. Pielow, E.C. (1997): An introduction to Mathematical ecology, John Wiley and Sons, New York
4. Gore, Anil and Paranhoe, S.A. (2000): A course on Mathematical and Statistical Ecology, Kluwer.

Course No. ST-409 **Title: Project Work**

Credit: 3 **Maximum Marks: 100**

The Project Work will spread over the whole semester. A project may be undertaken by a group of students. However, the project report shall be submitted by each member of the group separately. A project report shall clearly state the problem addressed, the methodology adopted, the assumption and the hypotheses formulated, any previous reference to the study undertaken, statistical analyses performed and the broad conclusion drawn. There shall be an external examiner and an internal examiner (preferably the supervisor of the student) for the evaluation of the project work. Out of the total 100 marks assigned to the project, 60 marks will be assigned on the evaluation of the project work separately by both the examiner and 40 marks will be assigned jointly by the examiners on the oral presentation and viva-voce.

Course No. SP-410 **Title: Practical I**

Credit: 3 **Maximum Marks: 100**

Syllabus: Practicals based on ST-401.

(Practical paper will be of 100 marks out of which 20 marks will be assigned on sessionals / tutorial / class tests / seminars in class / group discussions and 80 marks will be assigned on the end semester examination out of which 60 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva-voce).

Course No. SP-411 **Title: Practical II**

Credit: 3 **Maximum Marks: 100**

Syllabus: Practicals based on selected elective papers.

(Practical paper will be of 100 marks out of which 20 marks will be assigned on sessionals / tutorial / class tests / seminars in class / group discussions and 80 marks will be assigned on the end semester examination out of which 60 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva-voce).

Minor Electives for students of other programmes

First Semester

Course No. STM-101 **Title: Statistical Methods**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Descriptive Statistics: Measures of central tendency, dispersion, skewness and kurtosis for the sudy of nature of data.

Idea of correlation and regression for two and three variables; correlation coefficient, correlation ratio, multiple and partial correlations.

Important statistical distribution: Binomial, Poisson, Hypergeometric, Negative binomial, Normal, Uniform, Exponential and Multinomial distributions.

Statistical Inference: Concept of point estimation, interval estimation and testing.

Books recommended:

1. Bhat, B.R., Srivenkatarmana, T. and Rao Madhava, K.S. (1996): Statistics: A Biginner's Text, Vol I & II, New Age International (P) Ltd.
2. Snedecors, G.W. and Cochran, W.G. (1967): Statistical Methods, Iowa state University Press.
3. Goon, A.M., Gupta, K. and Dasgupta, B. (1991): Fundamentals of Statistics, Vol I, World Press, Calcutta.
4. Freund, J.E. (2001): Mathematical Statistics, Prentice Hall of India.
5. Mukhopadhyay, P. (1996): Mathematical Statistics, New Central Book Agency.

Second Semester

Course No. STM-201 **Title: Sampling theory, design of experiments and data analysis using softwares**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

Basic concept of sampling from a finite population; sampling versus complete enumeration; simple random sampling, sample size determination, stratified random sampling, systematic sampling, cluster sampling and multi-stage sampling (all sampling schemes without proof of expressions).

Analysis of variance technique: One way and two way classified data.

Design of experiment: Randomization, replication, local control; Completely randomized design, Randomized block design and Latin square design; factorial experiments.

Data analysis: Use of SPSS and SYSTAT softwares for data analysis, Use of parametric and non – parametric tests and the interpretation of the results.

Books recommended:

1. Cochran, W.G. (1977): Sampling Techniques, 3rd Edition, Wiley.
2. DesRaj (2000): Sample Survey Theory, Narosa Publishing House.
3. Das, M.N. and Giri, N (1986): Design and Analysis of Experiments, Springer Verlag.
4. Rohatgi, V.K. (1988): An Introduction to Probability and Mathematical Statistics, Wiley Eastern, New Delhi.
5. Gibbona, J.S. (1985): Non- Parametric Statistical Inference, 2nd Edition, Marcel Dekkar, Inc.

Third Semester

Course No. STM-301 **Title: Data analysis using regression models**

Credit: 3 **Maximum Marks: 100**
(a) Semester Examination: 60
(b) Semester/Internal Assessment: 40

(The course will involve a substantial amount of computing and the emphasis will be on applications and interpretations, rather than equations and derivations. Illustration will be done using R language)

Basic of linear regression with one predictor and multiple predictors, interactions, statistical inference, graphical display of data and fitted models.

Linear regression before and after fitting the model: linear transformations, centering and standardizing, logarithmic and other transformations.

Logistic regression with single predictor, interpreting the regression coefficients, logistic regression with interactions.

Generalized linear modes: Poisson regression, logistic- binomial models, regression (normally distributed latent data), ordered and unordered categorical regression, robust regression.

Simulation of probability models and statistical inferences, simulation for checking models fits.

Books recommended:

1. Weisberg, S. (1985): Applied Linear Regression, 2nd Edition.
2. Draper, N.R. and Smith, O. (2001): Applied Regression Analysis, Wiley.
3. Rawlings, John, O. (2001): Applied Regression Analysis, Springer Verlag.

* Students of Statistics shall offer Minor Electives from other programmes.

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