**Pt. RAVISHANKAR SHUKLA UNIVERSITY: RAIPUR**
**SCHOOL OF STUDIES IN STATISTICS**

**Syllabus for M.A./M.Sc. (Statistics) Semester Course 2016-17**

## FIRST SEMESTER

| S. No. | Paper | Subject | Theory Exam Marks | Internal assessment Marks | Total Marks | Credit points |
|---|---|---|---|---|---|---|
| 1 | I | Real Analysis | 80 | 20 | 100 | 04 |
| 2 | II | Statistical Methods | 80 | 20 | 100 | 04 |
| 3 | III | Applied Statistics | 80 | 20 | 100 | 04 |
| 4 | IV | Probability and Measure | 80 | 20 | 100 | 04 |
| 5 | V | Lab Course I : Practical Based on Courses II | | | 100 | 02 |
| 6 | VI | Lab Course II :Practical Based on Courses III | | | 100 | 02 |
| | | | **Total Credit points** | | | **20** |

## SECOND SEMESTER

| S. No. | Paper | Subject | Theory Exam Marks | Internal assessment Marks | Total Marks | Credit points |
|---|---|---|---|---|---|---|
| 1 | I | Linear Algebra | 80 | 20 | 100 | 04 |
| 2 | II | Stochastic Processes | 80 | 20 | 100 | 04 |
| 3 | III | Statistical Computing | 80 | 20 | 100 | 04 |
| 4 | IV | Sampling Theory | 80 | 20 | 100 | 04 |
| 5 | V | Lab Course I :Practical Based on Courses I & III | | | 100 | 02 |
| 6 | VI | Lab Course II :Practical Based on Courses IV | | | 100 | 02 |
| | | | **Total Credit points** | | | **20** |

## THIRD SEMESTER

| S. No. | Paper | Subject | Theory Exam Marks | Internal assessment Marks | Total Marks | Credit points |
|---|---|---|---|---|---|---|
| 1 | I | Multivariate Analysis | 80 | 20 | 100 | 04 |
| 2 | II | Inference - I | 80 | 20 | 100 | 04 |
| 3 | III | Operation Research-I | 80 | 20 | 100 | 04 |
| 4 | IV | Statistical Quality Control | 80 | 20 | 100 | 04 |
| 5 | V | Lab Course I : Practical Based on Courses I and II | | | 100 | 02 |
| 6 | VI | Lab Course II :Practical Based on Courses III and IV | | | 100 | 02 |
| | | | **Total Credit points** | | | **20** |

**FOURTH SEMESTER**

| S. No. | Paper | Subject | Theory Exam Marks | Internal assessment Marks | Total Marks | Credit points |
|---|---|---|---|---|---|---|
| 1 | I | Design of Experiment | 80 | 20 | 100 | 04 |
| 2 | II | Inference-II | 80 | 20 | 100 | 04 |
| 3 | III | Operation Research II | 80 | 20 | 100 | 04 |
| 4 | IV | Any of the following (Major Elective)<br>(a) Reliability and Life Testing<br>(b) Demography<br>(c) Econometrics | 80 | 20 | 100 | 04 |
| 5 | V | Lab Course : Practical Based on Courses I, II, and III | | | 100 | 02 |
| 6 | VI | Project Work | | | 100 | 02 |
| | | | **Total Credit points** | | | **20** |

## Grand Total of Credit Points = 80

Note: Students of Statistics shall offer Minor Elective from other programmes

## FIRST SEMESTER

**Paper I: Real Analysis**
**Paper II: Statistical Methods**
**Paper III: Applied Statistics**
**Paper IV: Probability and Measure**
**Paper V: Lab Course I: Practicals Based on Papers II**
**Paper VI: Lab Course II: Practicals Based on Papers III**

### Course –I
### Real Analysis

**UNIT-I**
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 and their convergence.

**UNIT-II**
Real valued function, Properties of real valued continuous function on $R^n$ , Uniform continuity, Sequences and series of functions, Uniform convergence. Power series and radius of convergence.

**UNIT-III**
Differentiation, maxima - minima of functions; functions of several variables, constrained maxima - minima of functions. Multiple integrals and their evaluation by repeated integration, Dirichlet and Lioulle's Theorem. Change of variables in multiple integration.

**UNIT-IV**
Reimann-Stieltjes integral of real valued function & its properties, Mean value theorem, Integration by parts and change of variables, Term by term integration, Differentiation & integration under the integral

sign. Improper integral, Uniform convergence in improper integrals, Test for absolute and conditional convergence.

**UNIT-V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**


1. Apostol, T.M. (1985). Mathematical Analysis, Narosa, Indian Ed.
2. Courant, R. and John, F. (1965). Introduction to Calculus and Analysis, Wiley.
3. Miller, K.S. (1957). Advanced Real Calculus, Harper, New York.
4. Rudin, Walter (1976). Principles of Mathematical Analysis, McGraw Hill.
5. Hewitt and Stromberg : Real and Abstract Analysis.
6. G. Das and S. Pattanayk : Fundamental of Analysis, TATA Mc Graw Hill.
7. Shanti Narayan: A course of mathematical analysis. S. Chand & Co. Ltd.


## Course -II

## Statistical Methods

**UNIT**-I

Frequency distribution, measures of location, dispersion and skewness, Moments and cumulats, moment generating function.

Simple correlation coefficient, Intra class correlation, Multiple and Partial Correlation. Linear and Multiple Regression, and their application.

**UNIT-II**

Testing of hypothesis, Level of significance, degrees of freedom, Central and Non-central chi-square, t and F- distributions, their properties and related tests. Sampling distributions of mean and variance of a sample from a normal population, sampling distribution of simple correlation coefficient in null case.

**UNIT-III**

Definition of probability, Bayes' theorem, Basic distribution function probability mass function, probability density function, joint, marginal and conditional p.m.f. . Random Variables and its mathematical expectations, conditional Expectation, Expectation of sum and multiplication of random variables, Markov Holder-Jensen and Liapounov inequalities.

Standard Discrete Distributions- Bernoulli, Binomial, Poisson, Geometric, Hyper geometric and Multinomial distribution. Limiting form of Binomial and Poisson distributions.

**UNIT-IV**

Standard continuous distributions-Uniform, Exponential, Normal Beta, Gamma and Cauchy distributions. Order Statistics-their distributions and properties. Joint & Marginal distributions of Order-Statistics.

**UNIT V**

Four short notes, one from each UNIT will be asked. Students have to answer any two.

**REFERENCES**


1. Dudewicz, E.J. and Mishra, S.N.(1988) : Modern Mathematical Statistics, Wiley, Int'I Student's Edition.
2. Rohatgi, V.K. (1984) : An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.
3. Rao, C.R. (1973) : Linear Statistical Inference and its Applications, 2/e, Wiley Eastern.
4. Weather ,Burn,C.E. : A first Course in Mathematical Statistics.

5. Keany,J.F. and Keeping,E.S. : Mathematics of Statistics Pt. I and II
6. Kendall,M.G. and stuart A : Advanced Theory of Statistics.
7. Mood ,gybrill and Boes : Introduction to theory of Statistics
8. Hogs and Craig : Mathematical Statistics
9. Goon,gupta and Dasgupta : Fundamental of Mathematical statistics Vol.I

## Course-III

### Applied Statistics

**UNIT-I**

Sources of demographic data –census, register, adhoc survey, hospital records, measurement of mortality ,crude death rate, age specific death rates, standardized death rate infant mortality rates, Complete and abridged life table-Kings method, Greville's method and method of Reed and Merrel, Construction of life table.

**UNIT-II**

Laws of mortality-Fitting of Makeham's law, Measurement of fertility-crude birth rate, general fertility rate ,age-specific birth rate, total fertility rate ,gross reproduction rate. The Stable and Stationary populations, Logistic curve for population growth, Population Projection.

**Unit III**

Different Component of time series, Measurement of secular trend: Fitting of mathematical curves, method of moving average, variate difference method, effect of elimination of trend ,merits and demerits of different methods of trend estimation. seasonal components, Determination of cyclical component., Periodogram analysis, Yule-Slutsky effect, correlogram Analysis.

**Unit IV**

Index number :meaning and costruction of index number,different formulae for constructing index numbers, tests of consistency of index number formulae, Chain base index numbers, Cost of living index numbers, Whole sale price index numbers. Demand Analysis: Demand and supply curves, Price elasticity of demand and supply, determination of demand curves from market data, Engel' Law and Engle's Curve.

**Unit V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**

1. O. S. Srivastava (1983) – A text book of demography ,Vikas Publishing House.
2. Parimal Mukhopadhaya (1999) – Applied Statistics, Books and Allied (P) Ltd.
3. V. K. Kapoor and S. C. Gupta: Applied Statistics, Sultan Chand and Sons.

## Course-IV

### PROBABILITY AND MEASURE

**UNIT-I**

Random experiment, Definition of Probability, Additive and multiplicative theorems of probability, Axiomatic approach to probability, Bayes Theorem. Classes of sets, fields, sigma-fields, minimal sigma-

field, Borel sigma-field in R_k, sequence of sets, limsup and liminf of a sequence of sets. Measure, Probability measure, properties of a measure, Lebesgue and Lebesgue- Steljes measure on R_k.

**UNIT-II**

Measurable set, Measurable functions, Random variables, sequence of random variables, almost sure convergence, convergence in probability (and in measure). Integration of a measurable function with respect to a measure, Monotone convergence theorem, Fatou's lemma, Dominated convergence theorem.

**Unit III**

Borel-Cantelli Lemma, Independence, Weak law and strong law of large numbers for iid sequences, Definition and examples of Markov dependence, Chebychev's Inequality, Probability generating function.

**Unit IV**

Convergence in distribution, characteristic function, uniqueness theorem, Levy's continuity theorem (statement only), CLT for a sequence of independent random variables under Lindeberg's condition, CLT for iid random variables.

**UNIT-V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**


1. Ash, Robert.(1972): Real Analysis and Probability. Academic Press.
2. Billingsley, P.(1986): Probability and Measure. Wiley.
3. Dudley, R. M. (1989): Real Analysis and Probability, Wadsworth and Brooks/Cole.
4. Kingman, J F C and Taylor, S.J. (1966). Introduction to Measure and Probability. Cambridge University Press.


**Paper V : Lab Course I – Practicals Based on Paper II**
**Paper VI : Lab Course II – Practicals Based on Paper III**

## SECOND SEMESTER

| | | |
|---|---|---|
| **Course – I** | **:** | **Linear Algebra** |
| **Course - II** | **:** | **Stochastic Processes** |
| **Course - III** | : | **Statistical Computing** |
| **Course - IV** | : | **Sampling Theory** |
| **Paper-V: Lab Course - I** | **:** | **Practical based on Papers I and III** |
| **Paper-VI: Lab Course - II** | **:** | **Practical based on Papers IV** |

**Course -I**

## Linear Algebra

**UNIT-I**

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. Determinants.

**UNIT-II**

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, rank and inverse of a matrix, null space and nullity, partitioned matrices, Kronecker product.

**UNIT-III**

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.

**UNIT-IV**

Characteristic roots and vectors, Cayley-Hamilton theorem, minimal polynomial, similar matrices, algebraic and geometric multiplicity of a characteristic root, spectral decomposition of a real symmetric matrix, reduction of a pair of real symmetric matrices, Hermitian matrices. Singular values and singular value decomposition, Jordan decomposition, extrema of quadratic forms, vector and matrix differentiation**.**

**UNIT-V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**


1. Graybill, F.A.(1983). Matrices with applications in statistics, 2nd Ed. Wadsworth.
2. Rao, C.R.(1973). Linear statistical inference and its applications, 2nd ed. John Wiley and Sons, Inc.
3. Searle, S.R. (1982). Matrix Algebra useful for Statistics. John Wiley and Sons. Inc.
4. Shanti Narayan: Matrices
5. Vashishtha, A. R.: Matrices


## Course– II
## Stochastic Processes

**UNIT-I**

Introduction to stochastic processes (sp's).; classification of sp's according to state space and time domain. Countable state Markov chains (MC's), Chapman-Kolmogorov equations; calculation of n-step transition probability and its limit. Stationary distribution, Classification of states; transient MC; Probability generating function. Properties of probability generating function .Laplace transform & its properties.

**Unit II**

Random walk and Gambler's ruin problem ; Applications from social, biological and physical sciences. Renewal theory: Elementary renewal theorem and applications. Statement and uses of key renewal theorem; study of residual life time process. Martingle in discrete time, inequality, convergence and smoothing properties.

**Unit III**

Discrete state space continuous time MC ; Kolmogorov- Feller differential equations ; Poisson process, birth and death process ; Applications to queues and storage problems. Wiener process as a limit of random walk; first - passage time and other problems.

**UNIT-IV**

Stationary process: weakly stationary and strongly stationary processes; Moving average and auto regressive processes. Branching process : Galton-Watson branching process, probability of ultimate extinction, distribution of population size. Statistical inference in MC and Markov processes.

**UNIT-V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**


1. Adke, S.R. and Manjunath, S.M. (1984): An Introduction to Finite Markov Processes, Wiley Eastern.
2. Bhat, B.R. (2000): Stochastic Models: Analysis and Applications, New Age International, India.
3. Cinlar, E. (1975): Introduction to Stochastic Processes, Prentice Hall.
4. Feller, W. (1968): Introduction to Probability and its Applications, Vol.1, Wiley Eastern.
5. Harris, T.E. (1963): The Theory of Branching Processes, Springur-Verlag.
6. Hoel, P.G., Port, S.C. and Stone, C.J. (1972): Introduction to Stochastic Processes, Houghton Miffin & Co.
7. Jagers, P. (1974): Branching Processes with Biological Applications, Wiley.
8. Karlin, S. and Taylor, H. M. (1975): A first Course in Stochastic Processes, Vol.1, Academic Press.
9. Medhi, J. (1982): Stochastic Processes, Wiley Eastern10. Parzen, E.(1962): Stochastic Processes, Holden-Day.


## Course - III

## Statistical Computing

**UNIT I**

FORTRAN Language: Constants & Variables, Control statements, Subroutine & Function subprograms Use of Excel for Statistical methods and graphical representation of data.

**Unit II**

Programming in C and in $C^{++}$: All Syntax ,Pointers, Arrys, Functions and Input / Output statements. Use of Statistical package. SPSS for large sample data analysis.

**Unit III**

**Numerical Analysis :** Finite differences & interpolation, Interpolation with unequal intervals, Central differences Interpolation-Gauss's, Stirling's and Bessel's Formulae.

**UNIT IV**

Numerical differentiation and integration, Trapezoidal rule, Simpson's one third, 3/8 rule, Weddle's `rule, Euler-Maclaurin Summation Formula, Newton-Cotes Formula, Gauss formula for approximation to factorials, Difference equation of first and second order.

**UNIT V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**


1. Balagurusamy,E.: Programming in ANSI C .Tata McGraw Hill.
2. Kanetkar ,Y.P.:Working with C.BPB Publication.

3. Reddy,R.N. and Ziegler,C.A.: FORTRAN-77 With Application for Scientiests and engineers,JAICO Publishing House Bombay,Calcutta & Madras.
4. Rajaraman: Computer Programming in FOTRAN-77,Prentice Hall.
5. B.W. Kernighan and D.M. Ritchie (1988). The C Programming Language, Second Edition. Prentice Hall.
6. W.H. Press, S.A. Teukolsky, W.T. Vellering, and B.P. Flannery (1993). Numerical Recipes in C, Second Edition. Cambridge University Press.
7. R.A. Thisted (1988). Elements of Statistical Computing. Champman and Hall.
8. Rajaraman,V.: Computer Oriented Numerical Methods.
9. Grewal, B. S.: Numerical methods.
10. Saxena, H. C.: Finite differences.

## Course -IV

## Sampling Theory

**UNIT-I**

Sample Surveys : concept of population sample and properties of estimator for finite populations, need for sampling, census and sample survey ,sample selection and sample size,Basic finite population sampling techniques ,simple random sampling with and without replacement, Estimation of population proportion ,Non-sampling errors, estimation of population mean in presence of non-response. Randomised response technique: Warner's method.

**UNIT-II**

Stratified sampling, systematic sampling and related results on estimation of population mean/total. Allocation problem in stratified sampling. Optimum allocation, Neyman allocation and Proportional allocation, estimation of gain in precision due to stratification, Post Stratification, Construction of strata, Effect of increasing number of strata. Comparison of stratified, systematic and simple random sampling, Systematic sampling under a linear model.

**UNIT-III**

Ratio regression estimators based on srswor and stratified methods of sampling. Bias of ratio estimate and optimum property of ratio estimate, Ratio estimate in stratified sampling, Regression estimate with pre-assigned and with estimated regression coefficient, comparison of ratio and regression estimate with sample mean. Unequal probability sampling: pps wr/wor methods [including Lahiri's scheme] and related estimators of a finite population mean [Desraj estimator and Murthy's estimator].

**UNIT-IV**

Cluster sampling. One stage cluster sampling, variance and cost functions ,sampling with probability proportional to cluster size,Hurwitz-Thompson estimation , two stage cluster sampling ,Allocation of sample to two stages :equal first stage UNIT comparison of two stage with one stage sampling. Double sampling ratio and regression estimate with and without cost aspect .

**UNIT-V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**

1. Cochran, W.G. : Sampling Techniques [3rd Edition, 1977). Wiley
2. Des Raj and Chandak (1998) : Sampling Theory. Narosa
3. Murthy, M.N. (1977). Sampling Theory & Methods. Statistical Publishing Society, Calcutta.
4. Sukhatme et al (1992). Sampling Theory of Surveys with Applications. lowa State University Press & IARS.

5. Singh, D. and Chaudhary, F.S. (1986). Theory and Analysis of Sample Survey Designs. New Age International Publishers.

**Paper V: Lab Course I – Practicals Based on Paper I and III**
**Paper VI: Lab Course II – Practicals Based on Paper IV**

## THIRD SEMESTER

| | | |
|---|---|---|
| **Course – I** | **:** | **Multivariate Analysis** |
| **Course - II** | **:** | **Inference I** |
| **Course - III** | **:** | **Operation Research I** |
| **Course - IV** | **:** | **Statistical Quality Control** |
| **Paper-V: Lab Course - I** | **:** | **Practical based on Papers I and II** |
| **Paper-VI: Lab Course – II** | **:** | **Practical based on Papers III and IV** |

## Course I

## Multivariate Analysis

**UNIT-I**

Gauss- Markov set-up, Estimability condition, best point estimates/interval estimates of estimable linear parametric functions ,Normal equations and Least squares estimates, Gauss-Markov Theorem, Introduction to fixed, mixed and random effects linear models. Analysis of variance for one way and two way classified data with equal and unequal number of observations per cells, Analysis of covariance model.

**UNIT-II**

Multivariate Normal Distribution and its properties, Reproductive property, transformation by a vector, singular /non-singular matrix, conditional distribution of a sub-set of multivariate normal variable/ Random sampling from a multivariate normal distribution. Maximum likelihood estimators of parameters. Distribution of sample mean vector. Wishart matrix - its distribution and properties, Characteristic function of Wishart distribution ,chi-square distribution as a particular case of Wishart distribution.

**UNIT-III**

Distribution of sample generalized variance. Null and non-null distribution of simple correlation coefficient. Null distribution of partial and multiple correlation coefficient. Distribution of sample regression coefficients. Distribution of Hotelling's T^2 statistic. Application in tests on mean vector for one and more multivariate normal populations and also on equality of the components of a mean vector in a multivariate normal population, Fisher-Behran statistic, Mahalanobis $D^2$ Statistic.

**UNIT-IV**

Multivariate linear regression model-estimation of parameters, tests of linear hypotheses about regression coefficients. Classification and discrimination procedures for discrimination between two multivariate normal populations - sample discriminant function, probabilities of misclassification and their estimation, classification into more than two multivariate normal populations. Principal components, Dimension reduction, Canonical variables and canonical correlation - definition, use, estimation and computation. Factor Analysis. An Introduction to cluster Analysis.

**UNIT-V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**


1. Cook, R.D. and Weisberg, S. (1982). Residual and Influence in Regression. Chapman and Hall.
2. Draper, N.R. and Smith, H.(1998). Applied Regression Analysis. 3rd Ed. Wiley.
3. Gunst, R.F. and Mason, R.L.(1980). Regression Analysis and its Applications – A Data Oriented Aproach. Marcel and Dekker.
4. Rao, C.R.(1973). Linear Statistical Inference and Its Applications. Wiley Eastern.
5. Weisberg, S. (1985). Applied Linear Regression. Wiley.
6. Andrson, T.W.(1983) : An Introduction to multivariate statistical analysis. 2nd Ed. Wiley. Giri, N.C.(1977) : Multivariate Statistical inference. Academic Press.
7. Kshirsagar, A.M. (1972) : Multivariate Analysis. Marcel Dekker.
8. Morrison, D.F. (1976) : Multivariate statistical methods. 2nd Ed. McGraw Hill.
9. Muirhead, R.J.(1982) : Aspects of multivariate statistical theory, J. Wiley.
10. Seber, G.A. F.(1984) : Multivariate observations. Wiley.
11. Sharma, S.(1996) : Applied multivariate techniques. Wiley.
12. Srivastava, M.S. and Khatri, C.G. (1979).: An introduction to multivariate statistics. North Holland.
13. Johnson, R. and Wychern (1992): Applied multivariate Statistical analysis, Prentice Hall, 3rd Ed.


## PAPER - II

## INFERENCE- I

**UNIT- I**

Unbiasedness , Consistency, efficiency and sufficiency of point estimator ,. Fisher –Neymann factorization theorem, Cramer Rao inequality, Bhattacharya bounds, Minimum Variance unbiased estimators, Minimal sufficient statistics,

**Unit –II**

Liklihood function, examples from standard discrete and continuous distributions. such as Bernoulli, Binomial, Possion, normal, exponential gamma etc) Methods of estimation – Method of maximum likelihood estimators, properties of maximum likelihood estimators. Method of scoring, method of moments, method of minimum chi-square, method of minimum variance, B.A.N. estimators.

**Unit- III**

Rao Blackwell theorem. Completeness of sufficient statistics. Completeness and Bounded Completeness, Koopman's theorem (Distributions admitting sufficient statistics),.Lehmann-Scheffe theorem, Invariant estimators. Confidence interval and confidence coefficients, Theory of confidence set, Relationship with the theory of hypothesis testing, Confidence interval for large samples.

**Unit-IV**

Loss function, Risk function, admissibility Minimax rule, Bays rule, Structure of Bay's rule, Construction of a Minimax rule, point and interval estimation as decision problem. State of nature,

payoff opportunity loss or regret, expected monitory value(EMV) criterion for decision making, maximum, maximax and minimax regret strategy, expected value of perfect information (EVPI).

**UNIT-V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**Reference :**


1. Kale, B.K. (1999): A first Course on Parametric Inference, Narosa Publishing House.
2. Rohatgi V. (1988): An Introduction to Probability and Mathematical Statistics. Wiley Eastern Ltd. New.Delhi (Student Edition)
3. Lehmann, E.L.(1986)-(Latest): Theory of point Estimation (Student Edition).
4. Lehmann, E.L.(1986): Testing Statistical hypotheses (Student Edition).
5. Rao, C. R. (1973): Linear Statistical Inference.
6. Zacks, S. (1971): Theory of Statistical Inference, John Wiley and Sons, New York.
7. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics. Wiley Series in Prob. Math. Stat., John Wiley and Sons, New York (International Student Edition)
8. Ferguson, T.S. (1996). A course on Large Sample Theory. Chapman and Hall, London.
9. Ferguson, T.S. (1967) : Mathematical Statistics, Academic Press.


## Course - III

## Operation Research I

**UNIT-I**

Definition and scope of Operational research ; phases in Operations Research ; models and their solutions ; decision-making under uncertainty and risk, use of different criteria ; The structure and formation of a linear programming problem,Graphical and simplex procedure,Two phase methods, and charne's-M method with artificial variables ; duality theorem .

**Unit II**

**T**ransportation and Assignment problems, Routing and traveling salesman problem .

**Unit III**

Inventory problems – Deterministic models of inventory , Economic Lot size formula ,instantaneous production case ,finite production rates situation ,cases when shortages are allowed /not allowed. Stochastic inventory models – a single period model with no set up cost.

**UNIT IV**

Basic characterics of queuing systems, Steady-state solutions of M/M/1 and M/M/c models with associated distributions of queue-length and waiting time. M/G/1 queue and Pollazcek Khinchine result. Steady-state solutions of M/Ek/1 and $E_k$/M/1 queues, Machine interference problem. Transient solution of M/M/1 queue .

Decision-making in the face of competition, two-person games, pure and mixed strategies, existence of solution and uniqueness of value in zero-sum games, finding solutions in 2x2, 2xm and mxn games. Non-zero sum games, co-operative and competitive games, equilibrium solutions and their existence in bi-matrix games. Nash equilibrium solution. ;

**UNIT V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**


1. Taha H.A. (1982) Operational Research : An Introduction ; Macmillan.

2. Hillier F.S. and Leiberman G.J. (1962) Introduction to Operations Research ; Holden Day.
3. Kanti Swarup, Gupta, P.K. and Singh M.M. (1985) Operations Research ; Sultan Chand& Sons.
4. Philips D.T., Ravindran A. and Solberg J. Operations Research, Principles and Practice.
5. Churchman C.W., Ackoff R.L. and Arnoff E.L.(1957) Introduction to Operations Research ; John Wiley.
6. Kleinrock L. (1975) Queueing Systems, vol. 1, Theory ; John Wiley
7. Saaty T. L. (1961) Elements of Queueing Theory with Applications ; McGraw Hill
10. Hadley G.and Whiting T.M. (1963) Analysis of Inventory Systems ; Prentice Hall
11. Starr M.K. and Miller D.W. (1962) Inventory Control-Theory and Practice ; Prentice Hall
12 . Mckinsey J.C.C. (1952) Introduction to the Theory of Games ; McGraw Hill
13. Wagner H.M. (1973) Principles of O.R. with Applications to Managerial Decisions ; Prentice Hall
14. Gross, D. and Harris, C. M. (1974) Fundamentals of Queueing Theory ; John Wiley

## Course - IV
## Statistical Quality Control

**UNIT-I**

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 ;

**UNIT-II**

Moving average and exponentially weighted moving average charts ; Cu-sum charts using V-masks and decision intervals ; Economic design of X-bar chart. Capability indices Cp, Cpk and Cpm ; estimation, confidence intervals and tests of hypotheses relating to capability indices for Normally distributed characteristics.

**UNIT-III**

Acceptance sampling plans for attribute inspection ; single, double and sequential sampling plans and their properties ; Bayesian sampling plan.

**UNIT-IV**

Plans for inspection by variables for one-sided and two-sided specifications ; Continuous sampling plans of Dodge type and Wald-Wolfiwitz type and their properties. 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

**UNIT V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**

1. Montgomery, D.C. (1985) Introduction to Statistical Quality Control ; Wiley
2. Ott, E.R. (1975) Process Quality Control ; McGraw Hill
3. Wetherill, G.B. (1977) Sampling Inspection and Quality Control ; Halsted Press
4. Wetherill, G.B. and Brown, D.W. (1991) Statistical Process Control, Theory and Practice ; Chapman and Hall.

5. Duncan, A. J.(1986): Quality Control and Industrial Statistics. 5th ed., Richard D. Ervin, Homewood, Illiions.
6. Ekambaram, S.K. (1963): The Statistical basis of quality control charts. Asia Publishing House, London.
7. Grant, E.L. & Leavenworth, R.S. (1988): Statistical Quality Control. 6th ed., McGraw-Hill Book Co., New York.
8. Bowker, A.H. & Goode, H.P. (1952): Sampling inspection by variables. McGraw-Hill Book Co., New York.
9. Schilling, E.G. (1982): Acceptance sampling in quality control. Marcel Dekker, Inc., New York.

**Paper V: Lab Course I – Practicals Based on Papers I and II**
**Paper VI: Lab Course II – Practicals Based on Papers III and IV**

## FOURTH SEMESTER

| | | |
|---|---|---|
| **Course – I** | **:** | **Design of Experiment** |
| **Course - II** | **:** | **Inference II** |
| **Course - III** | **:** | **Operation Research II** |
| **Course - IV** | : | **Reliability and Life Testing** |
| **Paper-V: Lab Course - I** | **:** | **Practical based on Papers I, II and III** |
| **Papers-VI: Lab Course - II** | **:** | **Project Work** |

## Course - I

## Design of Experiment

**UNIT I**
Introduction to design of experiments, Principle of design of experiments, Completely ranomized design, Ranomize block design, Latin square design. Missing plot technique - general theory and applications, efficiency of design.

**UNIT II**
Graeco Latin Square design, Cross-over designs, Analysis of covariance: Applications to standard designs with one concomitant variable, Testing the homogeneity of a group of regression coefficients. Split plot and split block experiments, efficiency of whole plot and sub plot treatments, merits and demerits of split plot experiments in comparison to factorial experiments.

**UNIT III**
General factorial experiments, factorial effects; best estimates and testing the significance of factorial effects ; study of 2 and 3 factorial experiments in randomized blocks ; Complete and partial confounding. Fractional replication for symmetric factorials, $2^n$ experiment with $2^k$ blocks per replicate, $3^2$ experiment.

**UNIT IV**
General block design and its information matrix. criteria for connectedness, balance and orthogonality, BIBD- Analysis with intrablock information and recovery of interlock information ; PBIBD, Youden design - intrablock analysis.
Application areas: Response surface experiments; first order designs and orthogonal designs.

**UNIT-V**

Four short notes, one from each unit will be asked. Students have to answer any two.

**REFERENCES**


1. Aloke Dey (1986) :Theory of Block Designs, Wiley Eastern.
2. Angela Dean and Daniel Voss (1999) : Design and Analysis of Experiments, Springer.
3. Das, M.N. and Giri, N.(1979) : Design and Analysis of Experiments, Wiley Eastern
4. Giri, N. (1986) : Analysis of Variance, South Asian Publishers
5. John, P.W.M. (1971) : Statistical Design and Analysis of Experiments, Macmillan.
6. Joshi, D.D. (1987) : Linear Estimation and Design of Experiments, Wiley eastern.
7. Montgromery, C.D.(1976): Design and Analysis of Experiments, Wiley, New York.
8. Pearce, S.C. (1984): Design of Experiments, Wiley, New York.


## Course-II
## Inference II

**Unit I**

***Test of Hypothesis:*** Concepts of critical regions, Test functions, two kinds of errors. Size function, power function, level, M. P. and U,M.P. Test, Neymann Pearson Lemma, M.P. test for simple null against simple alternative hypothesis ,UMP test for simple null hypothesis against one sided alternatives in one parameter exponential family .Unbiased test, UNIFORMELY most powerful unbiased test ,Type "A" critical region or locally most powerful unbiased test. Generalized form of Neyman Pearson lemma.

**Unit II**

Composite Hypothesis and similar regions, similar regions and complete sufficient statistics, Construction of most powerful similar regions, Unbiased critical regions, optimum regions and Sufficient Statistics. Likelihood ratio test, properties of likelihood ratio test, Likelihood ratio test for the mean of normal population, LR test for equality of means and variances of two and several normal populations.

**Unit III**

Sequential analysis: Wald's sequential probability ratio test (SPRT) with prescribed errors of two types, OC and ASN function of SPRT

**Unit IV**

Non parametric test, Rank test, Wilcoxon test, Median test, Sign test, Mann-Whitney U test, Wald-Wolfowitz run test, Kolomogorov-Smirnov test, One sample location problem, chi square test of goodness of fit.

**UNIT-V**

Four short notes, one from each unit will be asked. Students have to answer any two.

## REFERENCES


1. Kale, B.K. (1999): A first Course on Parametric Inference, Narosa Publishing House.

2. Rohatgi V. (1988): An Introduction to Probability and Mathematical Statistics. Wiley Eastern Ltd. NewDelhi (Student Edition)
3. Lehmann, E.L.(1986)-(Latest): Theory of point Estimation (Student Edition).
4. Lehmann, E.L.(1986): Testing Statistical hypotheses (Student Edition).
**5.** Rao, C. R. (1973): Linear Statistical Inference.
**6.** Zacks, S. (1971): Theory of Statistical Inference, John Wiley and Sons, New York.
**7.** Gibbons,J.D.(1985) : Nonparametric statistical inference 2nd Ed.,Marcel dekker,Inc.
8. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics. Wiley Series in Prob. Math. Stat., John Wiley and Sons, New York (International Student Edition)
9. Ferguson, T.S. (1996). A course on Large Sample Theory. Chapman and Hall, London.
10. Ferguson, T.S. (1967) : Mathematical Statistics, Academic Press.

## Course –III

## Operation Research II

**Unit I**

Repllacement problems : Replacement of items that fails and those that deteriorate ,group and individual replacement policies

**Unit II**

Network analysis,-Shortest Path Problem, Project planning and control with PERT and CPM

**Unit III**

Integer programming-Branch and Bound technique. Dynamic programming , Deterministic and Probabilistic Dynamic programming: decision tree and Bellman's Principle of optimality, models of dynamic programming,

**Unit IV**

Quadratic programming ,Kuhn-Tucker conditions for quadratic programming problem, Wolf's modified simplex method, Beale's method Goal Programming simulation :Monte Carlo method.

**UNIT V**

Four short notes, one from each unit will be asked. Students have to answer any two.

## REFERENCES


1. Taha H.A. (1982) Operational Research : An Introduction ; Macmillan.
2. Hillier F.S. and Leiberman G.J. (1962) Introduction to Operations Research ; Holden Day.
3. Kanti Swarup, Gupta, P.K. and Singh M.M. (1985) Operations Research ; Sultan Chand& Sons.
4. Philips D.T., Ravindran A. and Solberg J. Operations Research, Principles and Practice.
5. Churchman C.W., Ackoff R.L. and Arnoff E.L.(1957) Introduction to Operations Research ; John Wiley.


**Paper – IV: Any one of the following (Major Elective)**

**(a) Reliability and Life Testing**

**(b) Demography**

**(c) Econometrics**

### (a) Reliability and Life Testing

**Unit I**

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

**Unit II**

Life distributions ; common life distributions-exponential, Weibull, gamma 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.

**Unit III**

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 .

**Unit IV**

Stress-strength reliability and its estimation. Maintainability and availability, Maintenance and replacement policies ; availability of repairable systems ; modeling of a repairable system by a non-homogeneous Poisson process. Reliability growth models; Hollander-Proschan and Deshpande tests for exponentiality; tests for HPP vs NHPP with repairable systems. Basic ideas of accelerated life testing.

**Unit V**

Four short notes, one from each unit will be asked. Students have to answer any two.

## References


1. Barlow R.E. and Prochan F.(1985) ,Statistical theory of reliability and life testing ,Rinehart and Winston
2. Lawless J.F. (1982) ,Statistical Models and Methods of Life time data ; John Wiley .
3. Bain L.J. and Engelhardt (1991) ;statistical Analysis of Reliability and Life testing Models ,Marcel Dekker.
4. Nelson ,W (1982) ;Applied Life data analysis ; john Wiley .
5. Zacks S.;Reliability Theory ,Springer.


### (b) DEMOGRAPHY (Major Elective)

**UNIT – I**

Coverage and content errors in demographic data, Chandrasekharan-Deming formula to check completeness of registration data, adjustment of age data-use of Whipple, Myer and UN indices, Population transition theory.

**UNIT – II**

Measures of fertility; Stochastic models for reproduction, distributions of time of birth, inter-live birth intervals and of number of births (for both homogeneous and homogeneous group of women), estimation of parameters; estimation of parity progression from open birth interval data.

**UNIT – III**

Measures of Mortality; construction of abridged life tables, infant mortality rate and its adjustuemts, model life table. Stable and quasi-stable populations, intrinsic growth rate. Models of population growth and their filling to population data.

**UNIT – IV**

Internal migration and its measurement, migration models, concept of international migration. Methods for population projection, component method of population projection, Nuptiality and its measurements.

## References:


1. Kumar, R.(1986): Technical Demography, Wiley Eastern Lts.

2. Benjamin, B.(1969): Demographic Analysis, George, Allen and Unwin.
3. Chiang, C.L.(1968): Introduction to Stochastic Progression.
4. Cox, P.R. (1970): Demography, Cambridge University Press.
5. Keyfitz, N. (1977): Introduction to the Mathematics of Population-with Revision, Addison-Wesley, London.
6. Spiegelman, M.(1969): Introduction to Demographic Analysis, Harvard University Press.
7. Wolfenden, H.H.(1954): Population Statistics and Their Compilation, Am Actuarial Society.

### (c) ECONOMETRICS

**UNIT – I**

Nature of econometrics, the general linear model (GLM) and its extensions, ordinary least squares (OLS) estimation and prediction, generalized least squares (GLS) estimation and prediction, heteroscedastic disturbances, pure and mixed estimation.

**UNIT – II**

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 and stochastic regression, Instrumental variable estimation. Errors in variables.

**UNIT – III**

Autoregressive linear regression, lagged variables, distributed lag models, estimation of lags by OLS method, Koyck's geometric lag model, Simultaneous linear equations model and its generalization, identification problem, restrictions on structural parameters, rank and order conditions.

**UNIT – IV**

Estimation in simultaneous equations model, recursive systems, 2 SLS estimators, limited information estimators, k-class estimators. 3 SLS estimator, full information maximum likelihood method, prediction and simultaneous confidence intervals.

## References:

1 Apte, P.G.(1990): Text books of Econometrics, Tata Mcgraw Hill.
2 Cramer, J.S.(1971): Empirical Econometrics, North Holland.
3 Gujarathi, D.(1979): Basic Econometrics, McGraw Hill.
4 Intrulligator, M.D.(1980): Econometric models-Techniques and applications, Prentice Hall of India.
5 Johnston, J.(1984): Econometric methods. Third edition, McGraw Hill.
6 Klein, L.R. (1962): An introduction to Econometrics, Prentice Hall of India.
7 Koutsoyiannis, A. (1979): Theory of Econometrics, Macmillan Press.
8 Malinvaud, E. (1966): Statistical methods of Econometrics, North Holland.
9 Srivastava, V.K. and Gelies D.A.E.(1987): Seemingly unrelated regression equations models, Maicel Dekker.
10 Theil, H. (1982): Intruduction to the theory and practice of Econometrics, John Wiley.
11 Walters, A. (1970): An introduction to Econometrics, Macmillan & Co.
12 Wetherill, G.B.(1986): Regression analysis with application, Chapman Hall.

**Paper V : Lab Course I : Practical's based on Papers I, II and III**
**Paper VI : Project Work**