# PERIYAR UNIVERSITY

## PERIYAR PALKALAI NAGAR

## SALEM – 636 011

**DEGREE OF MASTER OF SCIENCE**

**CHOICE BASED CREDIT SYSTEM**

**SYLLABUS FOR M.Sc. STATISTICS**

**FOR THE STUDENTS ADMITTED FROM THE**

**ACADEMIC YEAR 2021 – 2022 ONWARDS**
**MASTER OF SCIENCE**

**BRANCH – II STATISTICS**

**(SEMESTER SYSTEM UNDER CBCS)**

**REGULATIONS**

## 1. OBJECTIVES OF THE COURSE

To transform graduates with sufficient strength in statistics so as to be employed in the Industry, Research and Development unit and Academic Institutions. The course is designed to impact professional knowledge and practical skills to the students.

## 2. CONDITION FOR ADMISSION

A candidate who have passed B.Sc Statistics / B.Sc Mathematics degree of Periyar University or any of the above degree of any other university accepted as per the norms set by the Government of Tamil Nadu as equivalent thereto, subject to such condition as may be prescribed thereto are permitted to appear and qualify for the M.Sc. Statistics degree examination of this university after a course of study of two academic years, under CBCS.

## 3. DURATION OF THE COURSE

The course for the degree of Master of Science in Statistics shall consist of two academic years divided into four semesters. Each semester consist of 90 working days.

## 4. COURSE OF STUDY

The course of study shall comprise instruction in the following subjects according to the syllabus and books prescribed from time to time.

## COURSE OF STUDY AND SCHEME OF EXAMINATION

| S. No. | Paper Code | Subject Title | Hours | | University Examinations | | |
|---|---|---|---|---|---|---|---|
| | | | Credits | Hours | Internal (25%) | External (75%) | Total |
| | | **I SEMESTER** | | | | | |
| | Core I | Real Analysis and Linear Algebra | 4 | 5 | 25 | 75 | 100 |
| | Core II | Measure Theory | 4 | 5 | 25 | 75 | 100 |
| | Core III | Distribution Theory | 4 | 5 | 25 | 75 | 100 |
| | Core IV | Sampling Theory | 4 | 5 | 25 | 75 | 100 |
| | Elective – I | Demography and Actuarial Statistics | 4 | 5 | 25 | 75 | 100 |
| | Core Practical I | Practical – I (Calculator Based) | | 3 | | | |
| | Core Practical II | Practical – II Statistical software Practical (Using R) | | 2 | | | |
| | | **Total** | **20** | **30** | **125** | **375** | **500** |
| | | **II SEMESTER** | | | | | |
| | Core V | Probability Theory | 4 | 6 | 25 | 75 | 100 |
| | Core VI | Statistical Estimation Theory | 4 | 6 | 25 | 75 | 100 |
| | Core VII | Statistical Quality Control and Reliability | 4 | 6 | 25 | 75 | 100 |
| | Core Practical I | Practical – I (Calculator based) | 4 | 3 | 40 | 60 | 100 |
| | Core Practical II | Practical – II – Statistical software Practical – (Using R) | 4 | 3 | 40 | 60 | 100 |
| | EDC | Business Communication | 4 | 3 | 25 | 75 | 100 |
| | Common Paper | Human Rights | 2 | 2 | 25 | 75 | 100 |
| | Internship | Compulsory Internship programme (15 days) Related to Curriculum-report to be submitted | - | - | - | - | - |
| | | **Total** | **26** | **30** | **205** | **495** | **700** |

| S. No. | Paper Code | Subject Title | Hours | | University Examinations | | |
|---|---|---|---|---|---|---|---|
| | | | Credits | Hours | Internal (25%) | External (75%) | Total |
| **III SEMESTER** | | | | | | | |
| | Core VIII | Testing Statistical Hypothesis | 5 | 6 | 25 | 75 | 100 |
| | Core IX | Multivariate Analysis | 5 | 6 | 25 | 75 | 100 |
| | Core X | Stochastic Processes | 5 | 6 | 25 | 75 | 100 |
| | Elective - II | Statistical Computing C++ | 4 | 6 | 25 | 75 | 100 |
| | Core Practical III | Practical – III (Calculator based) | - | 3 | - | - | - |
| | Core Practical IV | Practical – IV Statistical software Practical (Using PYTHON) | - | 3 | - | - | - |
| | | **Total** | **19** | **30** | **100** | **300** | **400** |
| **IV SEMESTER** | | | | | | | |
| | Core XI | Design and Analysis of Experiments | 5 | 6 | 25 | 75 | 100 |
| | Elective - III | Advanced Operations Research | 5 | 6 | 25 | 75 | 100 |
| | Elective – IV | Applied Regression Analysis | 5 | 6 | 25 | 75 | 100 |
| | Core Practical III | Practical – III (Calculator based) | 4 | 4 | 40 | 60 | 100 |
| | Core Practical IV | Practical – IV Statistical Software Practical – (Using PYTHON) | 4 | 4 | 40 | 60 | 100 |
| | Core Project | Project & Viva-Voce | 4 | 4 | 25 | 75 | 100 |
| | | **Total** | **27** | **30** | **180** | **420** | **600** |

**List of Core Subjects to be offered**

**CORE THEORY SUBJECTS**

1. Real Analysis and Linear Algebra
2. Measure Theory
3. Distribution Theory
4. Sampling Theory
5. Probability Theory
6. Statistical Estimation Theory
7. Statistical Quality Control and Reliability
8. Testing Statistical Hypothesis
9. Multivariate Analysis
10. Stochastic Processes
11. Design and Analysis of Experiments
12. Project & VIVA-VOCE

**CORE PRACTICALS**

1. Practical – I (Calculator based)
2. Statistical Software Practical-II (Using R)
3. Practical – III (Calculator based)
4. Statistical Software Practical-IV (Using PYTHON)

**ELECTIVE Subjects (Only four)**

1. Demography and Actuarial Statistics
2. Advanced Operation Research
3. Applied Regression Analysis.
4. Statistical Computing C++
6. Econometrics.

**Extra Disciplinary Course:**

1. Elements of Operations Research
2. Statistical Methods
3. Advanced Business Statistics

**Human Rights**. Common to all courses. Syllabus will be provided by the University.

**Examination:**

The examination shall be of three hours duration to each theory paper at the end of each semester. The candidate failing in any paper will be permitted to appear in the subsequent semester.

**Practical examinations should be conducted at the end of even semester:**

At the end of fourth semester, viva-voce will be conducted on the basis of Project/Dissertation submitted by the student .The viva-voce should be conducted jointly by the guide and the external examiner.

**Theory Papers:**

Total marks for each course (core / elective) is 100. 25 marks for Internal and 75 marks for University Examination. The components of Internal Assessment are:

| | | |
|---|---|---|
| **1. Test** | **=** | **10 Marks** |
| **2. Attendance** | **=** | **5 Marks** |
| **3. Seminar** | **=** | **5 Marks** |
| **4. Assignment** | **=** | **5 Marks** |
| **Total** | **=** | **25 Marks** |

**Practical:**

Total marks for each practical course is 100. 40 marks for internal and 60 marks for Written Examination. The components of Internal Assessment are:

| | | |
|---|---|---|
| **1. Record work** | **=** | **25 Marks** |
| **2. Test** | **=** | **10 Marks** |
| **3. Attendance** | **=** | **5 Marks** |
| **Total** | **=** | **40 Marks** |

**Project work:**

The Marks for the Project work is 100 and the components are:

**Internal Assessment:** **: 40 Marks**
(For two reviews 20+20 = 40)

**Evaluation:**

| | |
|---|---|
| Evaluation of Project report by External Examiner and Guide | **: 40 Marks** |
| Viva-Voce conducted by External Examiner & Guide | **: 20 Marks** |
| **Total** | **: 100 Marks** |

**QUESTION PAPER PATTERN**

**(a) For Theory**

- Total marks for each theory course (University examination) is **75**.
- The Question paper is divided into three parts.
- **PART-A** consists of 15 questions, three from each unit with multiple choice. Each question carries 1 mark. All questions should be answered. Total marks for PART-A is **15**.
- **PART-B** consists of 5 questions, one from each unit. Each question carries 5 marks. Any two questions should be answered. Total marks for PART-B is **10**.
- **PART-C** consists of 5 questions, either (or) type one from each unit. Each question carries 10 marks. All the questions should be answered. Total marks for PART-C is **50**.

**(b) For Practical**

- Total marks for each practical (university examination) is **60**.
- The candidate should attend 3 questions out of 5 questions each carrying 20 marks.

**Classification of Results:**

**(i) Passing Minimum:**

A candidate shall be declare to have passed the examination if the candidate secures not less than 50% of the marks in the Semester Examination and in IA in each course (or) practical. The candidate should get a minimum of 50% marks in semester examination (SE) as well as a minimum of 50% marks in Internal Assessment (IA), i.e., a minimum of 38 marks out of 75 in SE and minimum of 12 marks out of 25 in IA in the theory courses.

For practical courses, the distribution of marks will be 40 for IA & 60 for practical examination. The candidate should get a minimum of 20 marks out of 40 in IA and a minimum of 30 out of 60 in practical examination. The submission of record note book is a must in the practical examinations.

For the project work and viva-voce a candidate should secure 50% of the marks for pass. The candidate should compulsorily attend viva-voce examination to secure pass in the paper (Project).

Candidates who do not obtain the required minimum marks for a pass in a course or practical or project report shall be required to appear and pass the same at a subsequent appearance.

**(ii) Minimum Credits to be earned: 90 credits**

For Human Rights : 2 credits

**Total : 92 credits**

**(iii) Marks and Grades:**

The following table gives the marks, grade points, letter grades and classification to indicate the performance of the candidate.

Conversion of Marks to Grade Points and Letter Grade (Performance in a paper / course)

| RANGE OF MARKS | GRADE POINTS | LETTER GRADE | DESCRIPTION |
|---|---|---|---|
| 90-100 | 9.0-10.0 | O | Outstanding |
| 80-89 | 8.0-8.9 | D+ | Excellent |
| 75-79 | 7.5-7.9 | D | Distinction |
| 70-74 | 7.0-7.4 | A+ | Very Good |
| 60-69 | 6.0-6.9 | A | Good |
| 50-59 | 5.0-5.9 | B | Average |
| 00-49 | 0.0-4.9 | U | Re-appear |
| ABSENT | 0.0 | AAA | ABSENT |

$C_i$ = Credits earned for course *i* in any semester.

$G_i$ = Grade point obtained for course *i* in any semester

n = Refers to the semester in which such courses were credited.

**a) Semester:**

GRADE POINT AVERAGE (GPA) =

$$GPA = \frac{\text{Sum of the multiplication of grade points by the credits of the courses}}{\text{Sum of the credits of the courses in a semester}}$$

**b) The Entire Programme:**

CUMULATIVE GRADE POINT AVERAGE (CGPA) =

$$CGPA = \frac{\text{Sum of the multiplication of grade points by the credits of the entire programme}}{\text{Sum of the credits of the courses of the entire programme}}$$

| CGPA | GRADE | CLASSIFICATION OF FINAL RESULT |
|---|---|---|
| 9.5 - 10.0 | O+ | First class with Exemplary* |
| 9 and above but below 9.5 | O | |
| 8.5 and above but below 9.0 | D++ | First class with Distinction* |
| 8.0 and above but below 8.5 | D+ | |
| 7.5 and above but below 8.0 | D | |
| 7.0 and above but below 7.5 | A++ | First Class |
| 6.5and above but below 7.0 | A+ | |
| 6.0 and above but below 6.5 | A | |
| 5.5 and above but below 6.0 | B+ | Second class |
| 5.0 and above but below 5.5 | B | |
| 0.0 and above but below 5.0 | U | Re-appear |

* The candidates who have passed in the first appearance and within the prescribed semester of the PG Programme (Core, Elective, Non-major Electives and Extra-Disciplinary courses alone) are eligible.

**Dissertation:**

The topic of the dissertation shall be assigned to the candidate before the end of second semester. The student should prepare the plan of work for the dissertation at the end of second semester. In case the student wants to avail the facility from other organisations / university / laboratory, they will undertake the work with the permission of the guide and acknowledge the alien facilities utilized by them. The students should prepare three copies of dissertation and submit the same for the evaluation by Examiners.

**Format to be followed:**

The format / certificate for dissertation to be submitted by the students are given below.

**Format of the preparation of project work**

(a) Title page
(b) Bonafide Certificate
(c) Acknowledgement
(d) Table of Contents

**CONTENTS**

**Format of the Title Page:**

**TITLE OF THE DISSERTATION**

Dissertation submitted to the Periyar University

in partial fulfillment of the requirement for the Degree of

**Master of Science**

**in**

**STATISTICS**

**By**

**NAME OF THE STUDENTS**

**REG. NO**

(College

**COLLEGE NAME**

**(AFFLIATED TO PERIYAR UNIVERSITY)**

**Place with Pin Code**

MONTH & YEAR

**M.SC. STATISTIC**

**SEMESTER – I**

**CORE I - REAL ANALYSIS AND LINEAR ALGEBRA**

**UNIT I**

Introduction to n-dimensional Euclidean space and metric space – Countability, supremum and infimum of sets of real numbers – Bolzano-Weirstrass theorem. Convergence of sequences and series of real numbers – absolute and conditional convergence – Point-wise and uniform convergence – Tests for absolute, conditional and uniform convergence – Properties of uniform convergence.

**UNIT II**

Real valued functions - Limits and continuity and uniform continuity – Differentiability – Maxima and Minima of functions – mean value theorem, Taylor's theorem – functions of several variables.

**UNIT III**

Riemann-Stieltjes sums – Riemann-Stieltjes integral – Properties and Evaluation – Fundamental theorem – Differentiation under integral sign – Leibnitz's rule - Improper integrals - Multiple integrals and their evaluation by repeated integration.

**UNIT IV**

Vector Space – sub - space, Basis of vector space –Gram - Schmidt orthogonalization. Linear transformation (LT) and its properties – matrix of linear transformation –matrix of inverse transformation – change of basis, orthogonal transformation, dual space.

**UNIT V**

Linear equations – Generalized inverse of a matrix. Eigenvalues and eigenvectors of a LT –Diagonalizable LT, Cayley-Hamilton theorem and minimum polynomial for a LT – Eigenvalues of matrix polynomials. Quadratic forms and their classifications- Sylvester's law of inertia –reduction involving the eigen-values of the matrix.

**Books for Study and Reference:**


1. Goldberg, R.R. (1970) **Methods of Real Analysis**, Oxford & IBH, New Delhi.
2. Apostol, T.M. (1997) **Mathematical Analysis**, Narosa, New Delhi.
3. Somasundaram,D. (2002) **Mathematical Analysis**, Narosa, New Delhi.
4. Datta, K.E. (1991) **Matrix and Linear Algebra**, Prentice-Hall, New Delhi.
5. Rao, C.R. (1973) **Linear Statistical Inference and its Applications**, Wiley Eastern, New Delhi.
6. Searle, S.R. (1973) **Linear Models**, Wiley, New York.
7. Ramachandra Rao, A. and Bhimasankaran, P.(1992) **Linear Algebra**, Tata McGraw Hill, New Delhi.
8. Arora, S, (1988) **Real Analysis**, Satya Prakashan Mandir, New Delhi.
9. Ajit Kumar and Kumaresan, S, (2014) **A Basic Course in Real Analysis**, Chapman and Hall/CRC Press.
10. Goldberg, R. R, (1976), **Methods of Real Analysis**, Oxford & IBH Publishing Company, New Delhi.
11. Malik, S.C., and Arora, S, (2009), **Mathematical Analysis**, Second Edition, New Age International, New Delhi.
12. Rudin, W. (2016), **Principles of Mathematical Analysis**, Fourteenth reprints McGraw-Hill, New Delhi.


QP Pattern: Unit wise internal choice with maximum 75 marks

Part A: 15 × 1 = 15, Part B: 2 × 5 = 10 & Part C: 5 × 10 = 50

## CORE II - MEASURE THEORY

**Unit I**

Algebra of sets-Countable sets – field –monotonic field-monotonic class-field generated by a class of subsets-Borel sets- Borel field.

**Unit II**

Set functions – countably additive set functions – finitely additive set functions. Measure functions. Properties of measure functions – Outer measure functions – Extension measure – completion of a measure function (concepts only).

**Unit III**

Lebesque measure and its properties. Lebesque-Stieltjes measure-examples. Measurable functions- Borel measurable functions –Approximation theorem

**Unit IV**

Measure integration – Properties of integrals – sequence of Measurable functions – mode of convergence of measurable functions – monotone and dominated convergence theorems.

**Unit V**

Product measure – product measure functions-properties – Product measure theorem – Fubini's theorem (concept) and its applications in probability. Radon- Nikodym theorem (concept) and its applications.

**Books for Study and Reference:**


1. De Barra, G. (1991) **Measure theory and Integration**, Wiley Eastern Ltd.,
2. Basu, A.K. (1999) **Measure theory and Probability**, PHI.
3. Ash, R.B. (2000) **Probability & Measure Theory**, 2nd Edition, Academic Press.
4. Royden, H.L. (1968) **Real Analysis**, 2nd Edition, Macmillan.
5. Burrill.W. (1972) **Measure Integration and Probability**, Academic Press
6. Gupta, R.P. et al (1999) **Measure theory, Real Analysis – III**, Pragati Prakashan, Meerat.
7. Rohatgi, V.K. and Saleh, A.K.Md.E. **An Introduction to Probability and Statistics** (Second Edition). John Wiley & Sons, New York.

(2011)
8. Ross, S.M (2010) **A First Course in Probability,** Pearson Prentice Hall.
9. Bhat B. R, (2014) **Modern Probability Theory** (Fourth Edition), New Age International, New Delhi (Reprint 2015).
10. Ash, B.R, (1972), **Real Analysis and Probability**, Academic Press, New York.
11. Billingsley P, (2012) **Probability and Measure** (Third Edition), John Wiley & Sons, New York.
12. Feller, W. (1972), An Introduction to Probability Theory and Its Applications, Volume II, John Wiley & Sons, New York. (Reprint, 2008).

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## CORE III - DISTRIBUTION THEORY

### Unit I

Quick review of the following distributions – Discrete Distribution: Binomial, Poisson, Geometric, Hyper geometric, Multinomial, Negative binomial, Gamma and Beta distributions. Continuous Distribution: Normal, Bernoulli, Exponential, Lognormal and Cauchy (Derivation, application and Properties).Concept of truncated distribution and compound distribution (Binomial & Poisson).

### Unit II

Bivariate and multivariate distributions; Concepts of joint, marginal and conditional distributions. Detailed study of Bivariate Binomial and Bivariate normal distribution. Functions of random variables and their distribution: sum and difference, products and quotients of random variables.

### Unit III

Multivariate normal distribution and its properties: Marginal and conditional distribution; characteristic function and its uses. Distribution of linear functions of normal variables.

### Unit IV

Sampling distribution of statistics from normal samples leading to Normal, t, chi-square, and F (non-central) - properties of these distribution. Distribution of quadratic form.

### Unit V

Order statistics and their distribution; single & two order statistics. $r^{th}$ order statistics Distribution of median, range. Asymptotic distribution of extreme order statistics.

### Books for Study and Reference:


1. Hogg, R.V and Craig, A.T. (1972) — **An Introduction to Mathematical Statistics**, 3rd Edition, Amerind.
2. Anderson.T.W. (1983) — **An Introduction to Multivariate Statistical Analysis**, 2nd Edition, John Wiley.
3. Johnson and Kotz. (1970) — **Distributions in Statistics**, Vol I, II and III, John Wiley & Sons, New York.
4. Mood, Graybill and Boes. (1974) — **Introduction to the theory of statistics,** 3rd Edition. McGraw Hill.
5. Parimal Mukhopadhyey. (2006) — **Mathematical Statistics,** 3rd edition, New Central Book Agency.

| | | |
|---|---|---|
| 6. | Johnson, N.L Kotz, S. and Balakrishnan, N. (2014) | **Continuous Univariate Distributions, Vol. II,** Wiley , Singapore. |
| 7. | Rohatgi, V.K. and Saleh, A.K.MD.E. (2011) | **An Introduction to Probability and Statistics**, Wiley, New Delhi. |
| 8. | Johnson, N. L., Kotz, S., and Balakrishnan, N. (2004) | **Continuous Univariate Distributions,** Vol.I, John Wiley and Sons (Asia), Singapore. |
| 9. | Rao, C. R. (2009). | **Linear Statistical Inference and Its Applications**, Second Edition, John Wiley and Sons, New York. |
| 10. | Mood, A.M., Graybill, F.A., and Boes, D.C, (1974) | **Introduction to the Theory of Statistics**, Third Edition, McGraw-Hill International Edition. |


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## CORE IV - SAMPLING THEORY

**UNIT I**

Ratio Estimator: Approximate variance – Confidence limits – Comparison of the Ratio estimator with mean per unit – Conditions under which Ratio estimator is a BLUE – Bias term – Separate and combined ratio estimators – Unbiased Ratio Type estimator (Hartley and Ross).

Regression Estimators – Regression estimates with pre assigned "b" – sample estimate of variance – Bias – Regression estimators in Stratified Sampling.

**UNIT II**

Varying probability sampling: Cumulative total method and Lahiri's method. Estimation in PPS sampling with replacement, and without replacement; General selection procedures, Narian's Scheme of sample selection and Sen-Midzuno method – Ordered estimator: Des Raj, Unordered estimators: Hurwitz – Thompson estimator and Murthy's estimator.

**UNIT III**

Cluster Sampling: Equal cluster sampling – Estimators of mean and variance, optimum cluster size, Unequal cluster sampling – Estimators of mean and variance, varying probability cluster sampling –

**UNIT IV**

Two stage sampling – variance of the estimated mean. Multiphase sampling: Double sampling for stratification – Optimum allocation – Estimated variance in Double sampling for stratification.

**UNIT V**

Sources of errors in Surveys – A mathematical model of the effects of call-backs – a mathematical model of the errors of measurement – Interpenetrating subsampling method.

**Books for Study and Reference:**


1. Ardilly, P. and Yves T. (2006) **Sampling Methods: Exercise and Solutions,** Springer, New York.
2. Desraj (1976) **Sampling Theory**, McGraw Hill, New York.
3. Mukhopadyay, P. (2007) **Survey Sampling,** Narosa Publications, New Delhi.

4. Singh, D and Choudhary, F.S. (1977) **Theory and Analysis of Sample Survey Designs,** Wiley Eastern, New Delhi.

5. Sukhatme, P.V. and Sukhatme, B.V. (1970) **Sampling Theory Surveys with Applications,** 2/e, Iowa State University Press,Iowa.

6. Kish, L. (1961) **Survey Sampling**, Wiley, New York.

7. Murthy, M.N (1997) **Sampling Theory and methods**, Statistical Publishing Society, Calcutta.

8. Cochran, W.G, (2007) **Sampling Techniques**, Third Edition, John Wiley & Sons, New Delhi.

9. Singh, D and Choudhary, F.S, (1977), **Theory and Analysis of Sample Survey Designs**, Wiley Eastern Ltd, New Delhi.(Reprint 1986).

10. Thompson, S.K, (2012), **Sampling**, John Wiley and Sons, New York.

11. Sampath S (2001), **Sampling Theory and Methods**, The new age international Ltd. New Delhi.


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## Elective I - DEMOGRAPHY AND ACTUARIAL STATISTICS

**Unit I**

Demographic data – sources, coverage and content errors in demographic data. Use of balancing equations and Chandrasekaran Deming formula. Vital Registration system – Adjustment of age data - use of Whipple, Myer and UN Indices – Smoothing of age data.

**Unit II**

Measures of fertility: CBR, GFR, TFR, GRR and NRR - stochastic models for reproduction, Distribution of time to first birth, inter-live birth intervals and number of birth for homogenous group of women. Measures of mortality – construction of abridged life table methods by JIA, Reed and Merrel, Greville's and Kings.

**Unit III**

Utility theory – Insurance and utility theory. Models for individual claims and their sums – Life tables and its relation with survival function.

**Unit IV**

Life table function at non-integer age (fractional ages). Analytical laws of mortality – Gompertz's law and Makeham's law. Select and ultimate and aggregate mortality tables.

**Unit V**

Multiple life function – joint life and lost survivor status – Insurance and annuity benefits through multiple function.

**Books for Study and Reference:**


1. Ramkumar. R (1986) **Technical Demography,** Wiley eastern Ltd, New Delhi.
2. Rogers.A. (1975) **Introduction to Mathematical Demography,** Johnwiley, Newyork.
3. Biswas.S. (1988) **Stochastic processes in Demography and applications**, Wiley eastern limited.
4. A Listoris Neill. (1977) **Life contingencies**.
5. Bowers, N.L. Gerber.H.V. Hickman J.C, Jones D.A. and Nesbitt.C.J. (1986) **Actuarial mathematics,** Society of Actuarial, Ithaca, Illinois, USA (Second edition).

6. Dixit et all (2008) **Mathematical basis of life assurance, IC 81,** Insurance Institute of India, Bombay.

7. Benjamin, B. (1975) **Demographic Analysis**, George Allen and Unwin, London.

8. Cox, D.R. (1978) **Demography**, Cambridge University Press,Cambridge.

9. Gibbs, J.P. (2012) **Urban Research Methods. Literary Licensing**, LLC,WhiteFish, USA.

10. Keyfliz, N. and Caswell, H. (2006) **Applied Mathematical Demography,** Springer, New York.

11. Spiegelman, M. (1969) **Introduction to Demographic Analysis,** Harvard University Press, Harward.


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Part A: 15 × 1 = 15, Part B: 2 × 5 = 10 & Part C: 5 × 10 = 50

## CORE V - PROBABILITY THEORY

### Unit I

Probability measure – properties – Discrete probability space and general probability space, conditional probability space. Functions and inverse functions – Random variables – Induced probability space by random variables.

### Unit II

Distribution functions – properties – Decomposition theorem – Correspondence theorem – Distribution function of vector random variable - conditional distribution function – properties – Concept of Independence – Kolmogorov 0-1 Law – Borel Cantelli Lemma.

### Unit III

Expectation and moments – properties, conditional expectation – properties. Inequality – Markov, Holder, Jenson, Chebychev's and Liapounov. Convergence of sequence of random variables – modes of convergence and their relationship.

### Unit IV

Characteristic Function of random variables – properties – Inversion theorem – Simple examples – Uniqueness theorem, Levy continuity theorem (statement only).Law of Large numbers – WLLN for independent and i.i.d case – SLLN for independent and i.i.d case.

### Unit V

Weak and complete convergence of distribution function – Helly - Bray theorem. Central Limit theorem -generalization of LLN, C.L.T for independent random variables – Liapounov's form, Lindeberg – Feller C.L.T for i.i.d random variables – Lindeberg – Levy C.L.T .

**Books for Study and Reference:**


1. Bhat B. R, (2014), **Modern Probability Theory** (Fourth Edition), New Age International, New Delhi (Reprint 2015).
2. Fisz, M (1963) **Probability Theory and Mathematical Statistics**, John Wiley, Sons, New York.
3. Ash, B.R, (1972) **Real Analysis and Probability**, Academic Press, New York.
4. Billingsley P, (2012) **Probability and Measure** (Third Edition), John Wiley & Sons, New York.
5. Feller, W. (1972) **An Introduction to Probability Theory and Its Applications**, Volume II, John Wiley & Sons, New York. (Reprint, 2008).
6. Rohatgi, V.K. and Saleh, A.K.Md.E. (2011) **An Introduction to Probability and Statistics** (Second Edition). John Wiley & Sons, New York.
7. Ross, S.M (2010). **A First Course in Probability,** Pearson Prentice Hall.


QP Pattern: Unit wise internal choice with maximum 75 marks

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## CORE VI - STATISTICAL ESTIMATION THEORY

**Unit I**

Criteria of Point Estimation – Standard parametric models of distributions. Consistent estimation of real valued parameters. Invariance of consistent estimators. Unbiasedness, Sufficiency, Neyman Factorization criterion, Exponential families, distribution admitting sufficient statistics.

**Unit II**

Completeness, Bounded completeness, Minimal Sufficient statistics, method of constructing minimal sufficient statistics - minimum variance unbiased estimators. Rao - Blackwell theorem, Lehmann- Scheffe theorem.

**Unit III**

Unbiased estimator, uniformly minimum variance unbiased estimator- (UMVUE) Necessary and sufficient condition for UMVUE-Inequality approach to UMVUE-Fisher measure of Information. Cramer - Rao Inequality. Different forms of Cramer-Rao Inequality. Chapman – Robbins bound. Efficiency of an estimator-Extension of Cramer-Rao Inequality. Bhattacharya bound.

**Unit IV**

Method of Maximum Likelihood Estimation. Cramer and Huzurbazar theorem Solution of likelihood equations – Method of scoring – Method of minimum variance bound estimation – Method of moments. Interval estimation – confidence level, construction of confidence intervals using pivots, shortest length confidence interval.

**Unit V**

Bayesian Inference – Bayes theorem – concepts of prior distribution and its classification – Posterior distribution. Bayes estimation – Bayes estimates for Binomial, Poisson and Normal distribution using conjugate priors. Bayes estimator under quadratic error loss function.

**Books for Study and Reference:**


1. Kale. B.K. (1999) — **A First Course on Parametric Inference**, Narosa publishing House.
2. Lehmann. E.L. (1983) — **Theory of Point Estimation**, John Wiley, NewYork.
3. Cassella and Berger. (2002) — **Statistical Inference**, Thompson, New Delhi.
4. Radhakrishna Rao.C. (1973) — **Introduction to Linear Statistical Inference and its Applications,** Wiley Eastern.

5. Bansal. A.K. (2007) **Bayesian parametric Inference,** Narosa publishing House, New Delhi.
6. Manoj Kumar Srivastava, Abdul Hamid khan &NamitaSrivasta (2014) **Statistical Inference – Theory of Estimation,** PHI Publications.
7. Rajagopalan M and Dhanavanthan P, (2012) **Statistical Inference**, PHI Learning Pvt. Ltd., New Delhi.
8. Mood A.M, Graybill F.A and Boes D.C, (1974) **Introduction to Theory of Statistics**, Third Edition, McGraw-Hill International Edition.
9. Rohatgi, V.K and Saleh, A.K.Md.E, (2011) **An Introduction to Probability and Statistics**, Second Edition, John Wiley & Sons, New York.
10. Kale, B.K, (2005) **A First Course in Parametric Inference**, Second Edition, Narosa Publishing House, New Delhi. (Reprint, 2007).


QP Pattern: Unit wise internal choice with maximum 75 marks

Part A: 15 × 1 = 15, Part B: 2 × 5 = 10 & Part C: 5 × 10 = 50

## PRACTICAL –I (CALCULATOR BASED)

(**Based on Core courses: Sampling theory, Statistical Estimation Theory & Demography)**

The Maximum mark is 100 with 40 marks for Internal and 60 Marks for the University examination. The candidate should attend 3 questions out of 5 questions each carrying 20 marks. The Core Practical-I examination should be conducted at the end of II Semester.

**Unit I**

(a) Estimation of population mean, total and SE in stratified Random Sampling
(b) Estimation of population mean, total and SE in Systematic sampling.
(c) Ratio estimation and Regression estimation for population mean, total and its variance (SRS).
(d) Estimation of mean, total and variance in Cluster sampling and two stage cluster sampling with equal size clusters.

**Unit II**

(a) PPS sampling with replacement.
(b) Double sampling for stratification.
(c) Double sampling for Ratio estimation & Regression estimation.

**Unit III**

(a) UMVUE in one parameter exponential family of distribution.
(b) Maximum likelihood estimation & Methods of Moments.
(c) Interval estimation based on i) Normal ii) t iii) $\chi^2$ iv) F distributions

**Unit IV**

Fitting of Population Growth Models

(a) Gompertz's Law.
(b) Makeham's Law.
(c) Logistic Law - Method of partial sums & Method of three selected points.

**Unit V**

(a) Computation of Mobility measures.
(b) Probability of living and dying rate of mortality.
(c) Estimation and other measures from mortality table.
(d) Construction of Abridged life tables
i) Reed and Merrell ii) JIA Method iii) Greville's methods

## PRACTICAL II - STATISTICAL SOFTWARE PRACTICAL – I (Using R)

The Maximum mark is 100 with 40 marks for Internal and 60 Marks for the University examination. The candidate should attend 3 questions out of 5 questions each carrying 20 marks. The Core Practical-II examination should be conducted at the end of II Semester.

**Problems Relating to:**

1. Using R command – Operations on vectors, logical vector, index vector and matrices
2. Graphical procedures – Bar charts, Box plots, Histograms using single & multiple groups.
3. Creating and Manipulation of data frames, using various user defined functions.
4. Calculations of probability functions and generation of random samples for various discrete and continuous distributions.
5. Writing R Functions for Descriptive statistics, Correlations and Regression coefficient
6. Statistical Inference : Confidence interval for Proportion, Mean, Median
7. Analysis of variance - One way and Two way ANOVA

## CORE VI - STATISTICAL QUALITY CONTROL AND RELIABILITY

**Unit I**

Statistical process control: Moving average control chart – EWMA Control chart. Basic principles and design of CUSUM control chart – two sided and one-sided procedures – V-mask technique, Tabular CUSUM and decision interval. Modified control chart. Process capability analysis using histogram, probability plotting and control chart – Process capability ratio.

**Unit II**

Acceptance sampling – lot formation – sampling inspection by attributes – single, double and multiple sampling plans – operations and its uses – OC, ASN, ATI and AOQ forms, AOQ, LTPD procedures risk and consumers risk and OC curve – Use of Dodge-Roming and other tables of plans.

**Unit III**

Sampling inspection by variable – merits and demerits of Variable sampling plan- known and unknown sigma variable sampling plan – derivation of OC curve and the parameters of the plan.

**Unit IV**

Continuous sampling plan by attributes – CSP-I and its modifications – concept of AOQL in CSPs – multi level continuous sampling plans – operation of multi level CSP of Lieberman and Solomon – Wald-Wolfowitz continuous sampling plans – sequential sampling plans by attributes – OC and ASN function.

**Unit V**

Concept of reliability, components and systems – life distributions reliability function, Hazard function, Hazard rate, failure rate, common life distributions – exponential, Weibull and Gamma distributions – Estimation of parameters, complete samples in exponential and Weibull distribution only. Coherent systems, reliability of Coherent system.

**Books for Study and Reference:**


1. Montgomery. D.C. (2005) **Introduction to Statistical Quality Control,** 5th edn. John V (For Unit – I, II & III)
2. Charles E. Ebling (2000) **An introduction to Reliability and Maintainability**. (For Unit – IV)
3. Sinha S.K. and Kale. S.K (1998) **Life testing and Reliability Estimation** ( For Unit – V)

| | | |
|---|---|---|
| 4. | Duncan, A.J. (2006) | **Quality Control and Industrial Statistics**, Irwin - Illinois. |
| 5. | Grant, E.L. and Leavenworth, R.S. (2000) | **Statistical Quality Control**,7/e, Tata McGraw Hill, New Delhi. |
| 6. | Wetherill, G.B. (1977) | **Sampling Inspection and Quality Control**, 2/e, Chapman and Hall, London. |
| 7. | Bowker, A.H. and Lieberman, G.J. (1982) | **Engineering Statistics**,2/e, Prentice Hall, New Delhi. |
| 8. | John T. Burr, (2004) | **Elementary Statistical Quality Control** (Second Edition), Marcel Dekker New York. |
| 9. | Montgomery, D.C. (2009) | **Introduction to Statistical Quality Control**, 6/e, Wiley India, New Delhi. |


QP Pattern: Unit wise internal choice with maximum 75 marks

Part A: 15 × 1 = 15, Part B: 2 × 5 = 10 & Part C: 5 × 10 = 50

# CORE VIII - TESTING STATISTICAL HYPOTHESES

**Unit I**

Testing of Hypotheses. Concepts of testing hypotheses. Non-Randomized and randomized test- Critical region, Test function, Two types of errors, Level of significance, Size of the test, Power function. MP test - Neyman - Pearson fundamental Lemma.

**Unit II**

UMP test, MLR property, UMP tests for one sided test in one parameter exponential and MLR family of distributions .Nonexistence of UMP test for simple hypotheses against two sided alternatives in one parameter exponential family.

**Unit III**

Invariant tests – Maximal invariant statistics - Generalized Neyman - Pearson fundamental Lemma (statement only).UMP test for two sided alternatives in one parameter exponential family .Unbiased test, UMP unbiased test, Similar test , Neyman Structure test, Likelihood Ratio test (Concepts & properties).

**UNIT IV**

Sequential Probability Ratio Test- Optimum properties of the SPRT- The Fundamental Identity of Sequential analysis, OC and ASN function of sequential plans. Simple examples – Application to standard statistical distributions.

**UNIT V**

Non-parametric test; Empirical distribution, Kolmogorov – Smirnov goodness of fit for one sample and two sample problems, Sign test, Run test, Wilcoxon Signed- Rank test, Median test, Mann- Whitney U test. Wald – Wolfowitz runs test, Kruskal – Wallis Test and Friedman's Test.

**Books for Study and Reference:**


1. Rohatgi, V.K. and Saleh, A.K.MD.E. (2011) — **An Introduction to Probability and Statistics**, 2/e,Wiley, New York.
2. Rao, C.R. (1998) — **Linear Statistical Inference and its applications**, Wiley Eastern, New Delhi.
3. Rajagopalan, M. and Dhanavanthan, P. (2012). — **Statistical Inference**.PHI Learning Pvt. Ltd., New Delhi.
4. Gibbons, J. D., and Chakraborti, S. (2010) — **Nonparametric Statistical Inference** (Fifth Edition).Taylor & Francis, New York.
5. Goon, A.M., Gupta, M. K., and Dasgupta, B. (1989) — An **Outline of Statistical Theory**, Vol. II, World Press, Kolkata.
6. Kale, B. K. (2005) — **A First Course in Parametric Inference** (Second Edition). Narosa Publishing House, New Delhi. (Reprint, 2007).


QP Pattern: Unit wise internal choice with maximum 75 marks

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# CORE IX - MULTIVARIATE ANALYSIS

## Unit I

Estimation of the mean vector and the covariance matrix of a multivariate normal distribution.Partial and multiple correlation coefficients and their null distribution.Concept of path analysis – construction of path diagram and its use in linear regression model.

## Unit II

Inference problems concerning the mean vector when the covariance matrix is known (one and two sample problems); likelihood ratio criterion and its application; Mahalanobis D-square and its application. Inference concerning the mean vector (s) when the covariance matrix is unknown (one and two sample problem); Generalized T-square statistics, its distribution and its application; The relationship between T-square and D-square.

## Unit III

Wishart distribution (WD) (no derivation) and its properties; characteristic function of WD and its uses; test for covariance matrix. Sphericity` test; test for the equality of covariance matrices; testing the independence of sets of variates. Multivariate analysis of variance (one way and two way classification concepts only).

## Unit IV

Canonical correlation and variates; Estimation and interpretation.Classification problems, standard of good classifications; procedure of classification with two or more populations with known and unknown distributions. Classification procedures when the parent distribution are normal; Estimation of misclassification probabilities; Fisher's discriminant function and its uses.

## Unit V

Principal component analysis; Definitions and maximum likelihood estimators.Computation and interpretation of principal components.Factor analysis - the basic model - common and specific factors – communality - Estimation of factor loadings.Principal factor method, maximum likelihood method - factor rotations. Cluster analysis - similarity and distance measures - clustering techniques; Hierarchical techniques and Agglomerative methods.

**Books for Study and Reference:**


1. Anderson. T.W. (1983) **An introduction to multivariate statistical analysis,** 2nd edition, John Wiley.
2. Johnson and Wichern (1996) **Applied multivariate statistical analysis,** 3rd edition, PHI (P) Ltd.
3. Morrison. D.F. (1978) **Multivariate statistical methods,** Academic 2nd edition, McGraw Hill.
4. Hair et all (2009) **Multivariate Data analysis,** 6th edition, Pearson Publications.
5. Kendall, M.G., Stuart, A. and Ord, K.J. (1973). **The Advanced Theory of Statistics**. (Fourth Edition), Vol. 2, Charles Griffin company Ltd.
6. Kotz, S., Balakrishnan, N. and Johnson, N.L. (2000). **Continuous Multivariate Distribution Models and Applications** (Second Edition). Volume 1, Wiley - Inter science, New York.
7. Mardia, K.V., Kent, J. T and Bibby, J. M. (1979) **Multivariate Analysis.** Academic Press, New York.
8. Rao, C.R. (2001) **Linear Statistical Inference and its Applications** (Second Edition), Wiley-Inter Science, New York.


QP Pattern: Unit wise internal choice with maximum 75 marks

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## CORE X - STOCHASTIC PROCESSES

**Unit I**

Introduction to stochastic process (SP) – classification of SP according to state space and time domain.countable state markov chain (MC). Chapman- Kolmogorov equations.Calculation of 'n' step transition probability.

**Unit II**

Discrete state space – continuous time MC. Kolmogorov differential equations. Poisson process, birth and death process .Application to queues and storage problem. Random walk.

**Unit III**

Markov process – continuous time and continuous state space - time homogenous markov process – Kolmogorov's equation. Wiener process as a limit of random walk, first passage time Diffusion process with Wiener process.

**Unit IV**

Stationary process and time series- wide sense and strict sense stationary process – moving average and auto regressive process. Covariance function - Bochner's function (statement), Khintchine's representation of wide sense stationary process. Renewal theory – renewal function and its properties – Elementary and key renewal theorems.

**Unit V**

Branching processes - properties of generating functions of Branching processes - Probability of ultimate extinction - Martingales in discrete time – Super martingales and sub martingales, Martingale convergence theorem and its applications.

**Books for Study and Reference:**


1. Medhi, J. (2017) **Stochastic Processes**, Fourth Edition, New Age International (P) Ltd. New Delhi.
2. Basu. A.K. (2003) **Introduction to stochastic processes,** Narosa Publishing House.
3. Ross. S.M. (1983) **Stochastic Processes,** Wiley, New York.
4. Karlin and Taylor.H.M. (1975). **First course in Stochastic Process**-Vol.I&II, Academic Press.
5. Cinlar, E. (2013**)** **Introduction to Stochastic Processes**, Courier Dover, New York.
6. Cox, D.R. and Miller,A.D (1984) **The Theory of Stochastic Processes**, Chapman &Hall, London.
7. Linda J.S. Allen (2011) **An Introduction to Stochastic Processes with Applications to Biology**, 2/e,Chapman& Hall/CRC, London.


QP Pattern: Unit wise internal choice with maximum 75 marks

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# ELECTIVE II – STATISTICAL COMPUTING C++

**Unit – I**

Object Oriented Programming (OOPs) Paradigm – Basic Concepts of OOPs – Object Oriented Languages. A Simple C++ Program – More C++ Statements – Structure of C++ Program. Tokens, Keywords – Identifiers and Constants – Basic Data Types – User-defined Data Types – Operator in C++ – Scope Resolution Operator – Expressions and their Types – Control Structures.

**Unit – II**

Functions in C++: Introduction – The main function – Function Prototyping – Inline Functions – Default Arguments – Function Overloading – Math Library Functions. Classes and Objects: Specifying a Class – A C++ Program with Class – Defining Member Functions – Nesting Member Functions – Private Member Functions – Arrays within a class – Friendly functions – Memory Allocation of Objects – Array of Objects – Local Classes.

**Unit – III**

Constructors – Copy Constructor – Dynamic Constructors – Constructing Two-dimensional Arrays, Destructors. Operator Overloading – Introduction – Defining Operator Overloading – Overloading Unary Operators – Overloading Binary Operators – Rules for Overloading Operators. Function Overloading – Function Overloading with Arguments – Special Features of Function Overloading.

**Unit – IV**

Inheritance: Introduction – Types of Base Classes – Types of Derivation – Public – Private – Protected – Defining Derived Classes –Single Inheritance – Making a Private Member Inheritable – Multilevel Inheritance – Multiple Inheritance – Hierarchical Inheritance – Hybrid Inheritance – Polymorphism – Introduction – Virtual Functions.

**Unit – V**

Managing Console I/O Operations: C++ Streams – C++ Stream Classes – istream, ostream, iostream, fstream, ifstream, ofstream, filebuff. Unformatted I/O Operations – Formatted I/O Operations –Managing output with Manipulators. Classes for File Stream Operations – Opening and Closing a file – Detecting end-of-file.

**Books for Study and Reference:**


1. E. Balagurusamy (2008) **Object Oriented Programming with C++**, 4th Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi.
2. Jesse Liberty (1999) **C++ Unleashed**, Techmedia, New Delhi.
3. Robert Lafore. (1988) **Object Oriented Programming in Turbo C++**, Galgotia Publications, New Delhi.
4. Venugopal, Rajkumar, Ravishankar(1999) **Mastering C++**, Tata McGraw-Hill Publishing Company Limited, New Delhi.


QP Pattern: Unit wise internal choice with maximum 75 marks

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# DESIGN AND ANALYSIS OF EXPERIMENTS

**Unit I**

Linear models - Estimability of linear parametric functions-Generalized Gauss-Markov theorem on linear estimation (BLUE) –Fixed, mixed and random effect models- ANOVA for one-way and two-way classified data – ANOCOVA for one-way and two-way classification with one concomitant variable.

**Unit II**

Introduction to designed experiments – Efficiency of CRD, RBD& LSD– Missing plot techniques for RBD and LSD with one (or) two missing observations – Need and scope of Split-plot design – SPD as main effect confounded design.

**Unit III**

General factorial experiments-analysis of symmetrical $2^n$ ($n \leq 4$),$3^n$ ($n \leq 2$),and asymmetrical (p x q) factorial – construction and analysis of confounded (complete and partial)

**Unit IV**

General block designs- concepts of connectedness, balancedness and orthogonality. – BIBD and its parametric relations – Information (C) matrix and criteria for connectedness of block designs - Intra and Inter block analysis of BIBD – Youden square design and its intra block analysis.

**Unit V**

PBIBD with 'm' associate classes – classifications and parametric relations of PBIBD (2) – Intra block analysis of PBIBD(2) – Need and scope of response surface experiments-applications of experimental designs to quality management technique.

**Books for Study and Reference:**


1. Joshi. D.D. (1987) **Linear Estimation and design of Experiments**, Wiley Eastern.
2. Das. M.N and Giri.N.O. (1979) **Design and Analysis of Experiments,** Wiley Eastern.
3. Montgomery. D.C.(1994) **Design and Analysis of Experiments,** 3rd edition, John Wiley.
4. Agarwal. B.L. (2010) **Theory and Analysis of experimental Designs,** CBS Publishers.

5. Anderson & Mclean. (1974) **Design of experiments : A realistic approach,** Marcel Dekker, I.C.

6. Cochran & Cox. (1992) **Experimental Designs,** 2nd edn, John Wiley & Sons.

7. Fisher, R. A. (1953) **Design and Analysis of Experiments**. Oliver and Boyd, London.

8. Cochran, W. G and Cox, G. M. (1957) **Experimental Design**, John Wiley &sons, New York.

9. Das, M. N and Giri, N. S. (1986) **Design and Analysis of Experiments**, 2/e, Wiley Eastern, New Delhi.

10. Panneerselvam, R. (2012) **Design and Analysis of Experiments**, Prentice Hall.

11. Searle, S.R. (2012) **Linear Models. John Wiley & Sons**, Inc., New York.

12. Mukhopadhaya, P, (2011) **Applied Statistics**, Books & Allied Ltd; 2nd Revised Edition.


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# ADVANCED OPERATION RESEARCH

**Unit I**

Linear Programming Problems – Graphical method, Simplex method – Big – M method – Two Phase method – Dual Simplex method

**Unit II**

Integer programming problem – All integer programming – Mixed integer programming – Gomory's cutting plane method – Branch and Bound method.

**Unit III**

Non –linear programming problem – Multivariable function. Constrained multivariable optimization with equality and inequality constraints.Lagrangian method – Khun – Tucker conditions.Quadratic programming problem (QPP) – Wolfe's modified simplex method – Beale's method.

**Unit IV**

Dynamic programming problem – Characteristics of DPP – Bellman's principles of optimality – General algorithm – Stage coach problem – Cargo loading model – Work force size model – Investment model –LPP as DPP.

**Unit V**

Queuing models – Specification and effectiveness measures. Steady – state solutions of M/M/1 and M/M/c models with associated distributions of queue – length and waiting time. Steady – state solution of $M/E_k/1$ and $E_k/M/1$ queues- M/G/1 queue and Pollazcek Khinchine result.

**Books for Study and Reference:**


1. Taha. H.A. (2011) **Operations Research- An Introduction**.9/e,. Prentice Hall, New Delhi.
2. Rao.S.S. (1992) **Optimization Theory & Application,** Wiley, New Delhi.
3. Gass, S.I. (1985) **Linear Programming, Methods and Applications**. Courier Dover, New York.
4. Hillier, F.S. and Lieberman, G.J. (2005) **Introduction to Operations Research**, 9/e, McGraw Hill, New York.

5. Hadley, G (1962) **Linear Programming**, Addison-Wesley Publishing Company, Reading, Mass.

6. Sharma, J.K. (2013) **Operations Research: Problems and Solutions**,5/e, Macmillan India, New Delhi.

7. Sharma, S.D. (2010) **Operations Research**, Kedarnath Ramnath, Meerut.

8. Rao S.S. (1972) **Optimization: Theory and Applications**, Wiley Eastern(P) Ltd., New Delhi

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# APPLIED REGRESSION ANALYSIS
## (IV SEMESTER)

**Unit – I**

Multiple Linear Regression. Estimation of Model parameters. Least square estimation of the regression coefficients-properties of least square estimators. Maximum likelihood estimation-Tests for the significance of regression- test on individual regression coefficients –Confidence interval on the regression coefficients- Confidence interval estimation of mean response-Prediction –Standard regression coefficients-Unit normal scaling-Unit length scaling.

**Unit – II**

Residual analysis. Definition and properties of residuals-methods of scaling residuals-Residual plots- PRESS statistic- formal test for lack of fit. Variance -Stabilizing transformation-transformations to linearize models-Generalized and weighted least squares. Indicator variables-concept and use.

**Unit – III**

Model building problem-variable selection-Stepwise regression methods. Multicollinearity - sources and effects of multicollinearity –Diagnostics and methods for detecting multicollinearity.

**Unit – IV**

Polynomial regression. Polynomial model in one variable. Piecewise Polynomial fitting (Splines) - Non parametric regression. Kernel regression – Locally Weighted regression. Polynomial model in two or more variables.

Non-linear regression-nonlinear least square-transformation to linear model-parameter estimation.

**Unit – V**

Generalized Linear Models (GLM).Logistic regression-Estimation of parameters in logistic regression models-Interpretation of parameters in logistic regression models.Poisson regression-GLM-link function and linear prediction- parameter estimation in GLM.

**Books for Study and Reference:**


1. Montgomery. D.C. Peck E.A. Vining. G.G. (2003) **Introduction to Linear Regression Analysis,** John Wiley &sons, Inc, New York.
2. Draper. N.R. and Smith. H. (1998) **Applied regression Analysis,** John Wiley
3. Chaterjee and Ali S. Hadi (1977) **Regression Analysis by example,** John Wiley.

4. R. F. Gunst and R. L. Mason(1980) **Regression Analysis and Its Application: A Data-Oriented Approach**, Marcel Dekker, New York.

5. Daniel, C. and Wood, F.S. (1999) **Fitting Equations to Data**, 2/e, Wiley, New York.

6. Hosmer, D.W, Lemeshow, S., and Sturdivant, R. X. (2013) **Applied Logistic Regression**, Third Edition, John Wiley and Sons.

7. Draper, N.R and Smith,H. (1998) **Applied Regression Analysis**, 3/e, Wiley, New York.


QP Pattern: Unit wise internal choice with maximum 75 marks

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## PRACTICAL – III (Calculator Based)

**(Based on papers: Multivariate Analysis, Testing of Hypothesis,**

**Design of Experiments and Statistical Quality Control & Operation Research)**

The Maximum mark is 100 with 40 marks for Internal and 60 Marks for the University examination. The candidate should attend 3 questions out of 5 questions each carrying 20 marks. The Core Practical-III examination should be conducted at the end of IV Semester.

**Unit I**

(a) Finding partial, multiple correlation & Regression coefficients from $\Sigma$ matrix.
(b) Testing for partial, multiple correlation and regression coefficients.
(c) Testing $H_o: \mu = \mu_o$ When $\sum$ is known & When $\sum$ is unknown.
(d) Testing $H_o: \mu^{(1)} = \mu^{(2)}$ When $\sum$ is known & When $\sum$ is unknown.
(e) MLE's for $\mu$ and $\Sigma$ in a p –variate normal distribution.
(f) Test for dispersion matrix of p- variate Normal distribution (All Asymptotic tests)
(i) $H_o: \sum = \sum_0$ ii) $H_o: \sum_1 = \sum_2$ iii) $H_o: \mu = \mu_o$ and $\sum = \sum_0$
g) First principal component and its variance –Extraction method

**Unit II**

(a) Most powerful test – Binomial, Normal, Exponential.
(b) UMP Test : One –sided - Normal, Exponential and two – sided Bernoulli
(c) UMPU Test : Binomial, Normal, Exponential
(d) Sequential Probability Ratio Test (SPRT)
i) Bernoulli ii) Normal iii) Exponential

(e) Non – Parametric Tests : Wilcoxon signed Rank Test , Mann – Whitney U Test, Kolmogorov – Smrinov ( One sample and Two Sample) Test.

**Unit III**

(a) Statistical Analysis of RBD with two observations missing.
(b) Statistical Analysis of LSD with two observations missing.
(c) Statistical analysis of $2^3$ and $3^2$ factorial experiments
(d) Statistical analysis of BIBD (intra block analysis only)

**UNIT IV**

(a) Construction of moving average control chart.
(b) Construction of EWMA control chart.
(c) Acceptance sampling plan for variables – construction of one sided - procedure schemes, known and unknown sigma plans – O.C.curves.

**Unit V**

(a) Integer Programming Problem :
i) Gomory's Cutting Plan Method for Pure IPP.
ii) Gomory's Cutting Plan Method for Mixed IPP.
(b) Quadratic Programming problem
i. Wolfe's modified Simplex Method
ii. Beale's Method

## STATISTICAL SOFTWARE PRACTICAL USING PYTHON

The Maximum mark is 100 with 40 marks for Internal and 60 Marks for the University examination. The candidate should attend 3 questions out of 5 questions each carrying 20 marks. The Core Practical-I examination should be conducted at the end of II Semester.

Unit : 1

Introduction to Python, Types of numeric data, strings, Basic output statements, List, tuples, and Files- Introduction, Control flow structures – if else statements, while, for loops,defining functions in python, Introduction to Program Design

**Unit - II**

Processing of text data and csv files, dictionaries; exception handling; Turtle graphics; Classes and objects; Inheritance

**Unit - III**

Diagrammatic representation using python: Plotting data in Python: Scatter plots, histogram, cumulative frequencies, error-bars, box plots, pie charts, grouped bar charts, Bivariate scatter plots.

**Unit - IV**

Statistical testing using python: One sample t-test, paired t-test, independent sample t-test, ANOVA- one way, Two way and $\chi^2$ – test. Analysis for correlation and regression.

**Unit - V**

Random Number Generation - Uniform random Generation using numpy, Generation of non-uniform random variables - Simple discrete random variables like Bernoulli, Binomial, Uniform and continuous random variable like Normal, Exponential - Box Muller Method, p - p plots, qq plots.

**Textbooks**

1. Schneider, David I, An Introduction to Programming Using Python, Pearson Education Limited2016.

2. Haslwanter, Thomas, An Introduction to Statistics with Python: With Applications in the LifeSciences, Springer 2016.

3. Asmussen, Søren, Glynn, Peter W. Stochastic Simulation: Algorithms and Analysis, Springer2007.

**Reference Books**

1. Ceder, Vernon L, The Quick Python Book, Manning Publications Co., Greenwich

2. Saha, Amit Doing math with Python: use programming to explore algebra, statistics, calculus,and more!, No Starch Press, 2015

3. https://machinelearningmastery.com/how-to-generate-randomnumbers-in-python/

## PROJECT WORK

Project/Dissertation work shall be carried out under the supervisor of a Faculty member on the recommendation of the Head of the Department. **Three copies** of the Project report should be submitted at least two weeks before the last working day of the fourth semester. The Marks for the Project work is 100 and the components are:

**Internal Assessment: : 40 Marks**

**(For two reviews 20+20 = 40)**

**Evaluation of Project report by External Examiner and Supervisor : 40 Marks**

**Viva-Voce by External Examiner and Supervisor : 20 Marks**

The Evaluation of the Project will be based on Project Report and a VIVA-VOCE examination to be conducted by the Supervisor and an External Examiner.

# ECONOMETRICS

## Unit I

Nature and scope of Econometrics: Production and cost analysis -price and income Elasticity of demand. Price Elasticity and supply – Torquivisits model of demand Inferior goods-Models building –Bias in construction of models.

## Unit II

General Linear Model (GLM) and its extension. Ordinary Least square (OLS) estimation and prediction .Generalized Least square (GLS) estimation and prediction and their properties – problem of hetroscedasticity and multicollinearity pure and mixed estimation. Grouping of observations and equations.

## UnitIII

Single equation linear model –dynamic case; Autocorrelation and its consequences

Testing for Autocorrelation; Theil's BLUS procedure .Estimation and Prediction Estimation of parameters of a linear model with auto correlated disturbances and distributed lag models – Errors in variable models.

## Unit IV

Simultaneous linear equation model – Examples. Identification problem .Estimation

Using LIM, Instrumental Variables. 2 –SLS methods.

## Unit V

K class estimators; Full information Maximum Likelihood methods .3-SLS estimators-Simultaneous LSE and integrated LST methods .Monte Carlo studies and simulation –Concepts of structural change –Tests of structural change.

**Books for Study and Reference:**


1. Johnston. (1984) **Econometrics models (3rd edition)**, McGraw Hill, Tokyo.
2. Intrulligator.M.D. (1980) **Econometric models :- Techniques and Applications**, Prentice Hall of India.

3. Walters. A. (1970) **An introduction to Econometrics** , McMillan & Co.
4. Gold Berger. (1964) **Econometric theory**, Wiley.
5. Allen. R.G.D. (1965) **Mathematical Economics**, McMillan & Co.
6. Maddala. (1977) **Econometrics**, McGraw Hill.

QP Pattern: Unit wise internal choice with maximum 75 marks

Part A: 15 × 1 = 15, Part B: 2 × 5 = 10 & Part C: 5 × 10 = 50

# Elements of Operations Research

**Unit I**

Operations Research: Introduction-Origin and development of O.R-Definition and Applications of O.R. – Models in O.R.-classification of models-advantages and limitations of models. General solution for O.R models.Methodology of O.R.

Linear programming problem. Formulation of LPP.

**Unit II**

Graphical method of solving LPP.Simplex method –Big M method.Concept of duality in LPP.Formulation of dual problems only.

**Unit III**

Transportation problems: Finding initial basic feasible solution-test for optimality by MODI method. Assignment Problem: Hungarian method of solving A.P. Maximization in Assignment problem.

**Unit IV**

Sequencing: problem of sequencing- basic terms used in sequencing- processing 'n' jobs through two machines- processing 'n' jobs through 'k' machines- processing two jobs through 'k' machines.

**Unit V**

Game Theory: Definition-types of games- The Maximin - Minimax principle. Games without saddle points (mixed strategies)-graphical method of 2 x n and m x 2 games - Dominance property.

**Books for Study and Reference:**


1. KantiSwarup. (2007) **Operations Research,** Sultan Chand & Sons, New Delhi.
2. Sharma. J.K. (2002) **Operations Research**, McMillan & co.
3. Kalavathy.S. (2002) **Operations Research,**Vikas Publishing House, New Delhi.


QP Pattern: Unit wise internal choice with maximum 75 marks

Part A: 15 × 1 = 15, Part B: 2 × 5 = 10 & Part C: 5 × 10 = 50

# Statistical Methods

**Unit I**

Definition of Statistics and its applications in various disciplines. Collection of data.Classification, tabulation and graphical representation of data. Construction of univariate and bivariate frequency distributions. Charts and Diagrams and Graphs: bar diagrams, Pie diagram. Histogram, frequency and cumulative frequency curves.

**Unit II**

Measures of central tendency: concept and uses. Mean, Median, Mode, Geometric Mean and Harmonic mean.

Measures of variation: concept and uses. Range, Quartile deviation, standard deviation and coefficient of variation.Measures of Skewness.

**Unit III**

Census and Sample surveys.Concept of sample and sampling-.Principles of sampling.Advantages and limitations of sampling. Random sampling: simple random sampling, Stratified random sampling. Systematic sampling and Cluster sampling.Non-random sampling: Quota sampling, convenience and Judgment sampling, snow ball sampling.

**Unit IV**

Simple linear correlation: meaning and its uses. Scatter diagram-Karl pearson (product moment) correlation-rank correlation.

Simple linear regression: meaning and its uses. Difference between correlation and regression. Regression equations.

**Unit V**

Definition and utility of Time series analysis. Components of Time series. Measurement of Trend: Method of moving averages and Method of Least Squares. Measurement of Seasonal variations: Method of Simple averages.

**Books for Study and Reference:**


1. Gupta. S.P. (2007) **Statistical Methods**, Sultan Chand & Sons, New Delhi.
2. Agarwal. D.R. (2003) **Quantitative Methods**, Virinda Publications, New Delhi.
3. Richard Levin. (2000) **Statistics for Management**, Prentice Hall India.


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