PANJAB UNIVERSITY, CHANDIGARH-160014 (INDIA)
(Estd. under the Panjab University Act VII of 1947—enacted by the Govt. of India)

FACULTY OF SCIENCE

SYLLABI

FOR

M.Sc. STATISTICS (SEMESTER SYSTEM)
EXAMINATIONS, 2014-2015

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APPLICABILITY OF REGULATIONS FOR THE TIME BEING IN FORCE

Notwithstanding the integrated nature of a course spread over more than one academic year, the regulations in force at the time a student joins a course shall hold good only for the examinations held during or at the end of the academic year. Nothing in these regulations shall be deemed to debar the University from amending the regulations subsequently and the amended regulations, if any, shall apply to all the students whether old or new.

Note:

A candidate for M.A examination shall offer Psychology or Sociology or Statistics or Public Administration only if he/she has completed the prescribed courses in an affiliated college or the Department concerned of this University.
GUIDELINES FOR CONTINUOUS INTERNAL ASSESSMENT (20%) FOR REGULAR STUDENTS OF POST-GRADUATE COURSES of M.Sc. Statistics (Semester System)
(Effective from the First Year Admissions for the Academic Session 2005-2006)

1. The Syndicate has approved the following guidelines, mode of testing and evaluation including Continuous Internal Assessment of students:
   (i) Terminal Evaluation : 80 %
   (ii) Continuous Assessment : 20 %
   (iii) Continuous Assessment may include written assignment, snap tests, participation in discussions in the class, term papers, attendance etc.
   (iv) In order to incorporate an element of Continuous Internal Assessment of students, the Colleges/Departments will conduct one written test as quantified below:

   (a) Written Test : 25 (reduced to 5)
   (b) Snap Test : 25 (reduced to 5)
   (c) Participation in Class Discussion : 15 (reduced to 3)
   (d) Term Paper : 25 (reduced to 5)
   (e) Attendance : 10 (reduced to 2)

   Total : 100 reduced to 20

2. Weightage of 2 marks for attendance component out of 20 marks for Continuous Assessment shall be available only to those students who attend 75% and more of classroom lectures/seminars/workshops. The break-up of marks for attendance component for theory papers shall be as under:

<table>
<thead>
<tr>
<th>Attendance Component</th>
<th>Mark/s for Theory Papers</th>
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</thead>
<tbody>
<tr>
<td>(a) 75 % and above upto 85 %</td>
<td>1</td>
</tr>
<tr>
<td>(b) Above 85 %</td>
<td>2</td>
</tr>
</tbody>
</table>

3. It shall not be compulsory to pass in Continuous Internal Assessment. Thus, whatever marks are secured by a student out of 20% marks, will be carried forward and added to his/her score out of 80 %, i.e. the remaining marks allocated to the particular subject and, thus, he/she shall have to secure pass marks both in the University examinations as well as total of Internal Continuous Assessment and University examinations.

4. Continuous Internal Assessment awards from the affiliated Colleges/Departments must be sent to the Controller of Examinations, by name, two weeks before the commencement of the particular examination on the proforma obtainable from the Examination Branch.

SPECIAL NOTES:

i) The theory question paper will be of 80 marks and 20 marks will be for internal assessment.
ii) For the private candidates, who have not been assessed earlier for internal assessment, the marks secured by them in theory paper will be increased proportionately to maximum marks of the paper in lieu of internal assessment.
   The paper setter must put note (ii) in the question paper.
iii) In the case of Post Graduate Courses in the Faculties of Arts, Science, Languages, Education, Design and Fine Arts, and Business Management & Commerce, falling under the purview of Academic Council, where such a provision of Internal Assessment/Continuous Assessment already exists, the same will continue as before.
iv) The marks obtained by a candidate in Continuous Internal Assessment in Postgraduate Classes from the admissions of 2004 will be shown separately in the Detailed Marks. Card (D.M.C.).
PANJAB UNIVERSITY CHANDIGARH

Outlines of Text, Syllabi and Courses of Reading in the Subject of Statistics for M.Sc. (Statistics) I-IV semester for the session 2014-15 i.e., 1st and 3rd Semesters November/December 2014 and 2nd & 4th Semesters April/May 2015 Examinations, respectively.

<table>
<thead>
<tr>
<th>Course No.</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td><strong>Semester-I</strong></td>
<td></td>
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<tr>
<td>Stat-101</td>
<td>Linear Algebra</td>
<td>4</td>
</tr>
<tr>
<td>Stat-102</td>
<td>Distribution Theory</td>
<td>4</td>
</tr>
<tr>
<td>Stat-103</td>
<td>Statistical Methods with Packages (Theory 3/4, Practical 1/4)</td>
<td>4</td>
</tr>
<tr>
<td>Stat-104</td>
<td>Course selected from module</td>
<td>4</td>
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<tr>
<td><strong>Semester- II</strong></td>
<td></td>
<td></td>
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<tr>
<td>Stat-201</td>
<td>Statistical Computing using FORTRAN (Theory 1/2, Practical 1/2)</td>
<td>4</td>
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<tr>
<td>Stat-202</td>
<td>Estimation and Testing of Hypotheses (Theory 3/4, Practical 1/4)</td>
<td>4</td>
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<tr>
<td>Stat-203</td>
<td>Sampling Theory and Official Statistics (Theory ¾, Practical ¼)</td>
<td>4</td>
</tr>
<tr>
<td>Stat-204</td>
<td>Course selected from module</td>
<td>4</td>
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<tr>
<td><strong>Semester III</strong></td>
<td></td>
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<tr>
<td>Stat-301</td>
<td>Nonparametric Inference (Theory 3/4, Practical 1/4)</td>
<td>4</td>
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<tr>
<td>Stat-302</td>
<td>Statistical Process and Quality Control (Theory 3/4, Practical 1/4)</td>
<td>4</td>
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<tr>
<td>Stat-303</td>
<td>Linear Inference (Theory 3/4, Practical 1/4)</td>
<td>4</td>
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<tr>
<td>Stat-304</td>
<td>Course selected from module</td>
<td>4</td>
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<tr>
<td><strong>Semester IV</strong></td>
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<tr>
<td>Stat-401</td>
<td>Multivariate Analysis (Theory 3/4, Practical 1/4)</td>
<td>4</td>
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<tr>
<td>Stat-402</td>
<td>Design and Analysis of Experiments (Theory 3/4, Practical 1/4)</td>
<td>4</td>
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<td>Stat-403</td>
<td>Course selected from module</td>
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<td>Stat-404</td>
<td>Course selected from module</td>
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(iii)
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<tr>
<th>Module</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>M 1</td>
<td>Actuarial Statistics</td>
<td>4</td>
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<tr>
<td>M 2</td>
<td>Categorical Data Analysis</td>
<td>4</td>
</tr>
<tr>
<td>M 3</td>
<td>Econometrics</td>
<td>4</td>
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<tr>
<td>M 4</td>
<td>Economic Statistics</td>
<td>4</td>
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<tr>
<td>M 5</td>
<td>Advanced Inference</td>
<td>4</td>
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<tr>
<td>M 6</td>
<td>Measure and Probability Theory</td>
<td>4</td>
</tr>
<tr>
<td>M 7</td>
<td>Operations Research</td>
<td>4</td>
</tr>
<tr>
<td>M 8</td>
<td>Real and Complex Analysis</td>
<td>4</td>
</tr>
<tr>
<td>M 9</td>
<td>Reliability</td>
<td>4</td>
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<tr>
<td>M 10</td>
<td>Simultaneous Inference</td>
<td>4</td>
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<tr>
<td>M 11</td>
<td>Statistical Simulation and Computation</td>
<td>4</td>
</tr>
<tr>
<td>M 12</td>
<td>Stochastic Processes</td>
<td>4</td>
</tr>
<tr>
<td>M 13</td>
<td>Survival Analysis</td>
<td>4</td>
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ANY OTHER COURSE WHICH THE BOARD OF CONTROL MAY DECIDE TO OFFER.
NOTES:

1. The Board of Control shall decide which papers from the selected modules shall be offered in M.Sc. (Statistics) 1st, 2nd, 3rd and 4th Semesters.

2. Each paper/course of 4 credits shall carry hundred marks.

3. A student shall be required to earn a total of 64 credits to become eligible for the award of M.Sc. (Statistics) degree.

4. For a uniform spread of the syllabus over four semesters, a student shall be required to attend classes for courses amounting to a minimum of 12 credits and a maximum of 20 credits each semester in the four-semesters M.Sc. (Statistics) programme.

5. The composition, duration and the general style of the theory papers in the final examination in each semester will be decided upon by the Board of Control.

6. The mode of conduct of practical examinations in each semester will be decided upon by the Board of Control.

7. In the final examination of the course, which is divided into theory and practical parts, the distribution of the weightage for the practical part will be as follows:
   (a) Practical questions (3/5)
   (b) Viva-Voce (1/5)
   (c) Record of practicals (1/5)

8. The practical marks in course Stat-201: Statistical Computing using FORTRAN will be based entirely on Internal Assessment.

9. The practical marks in course M 11 Statistical Simulation & Computation will be based entirely on Internal Assessment.

10. In the final examination of the course, which is divided into theory and practical parts, the theory and practical Papers will be treated as independent units for passing in a paper.

11. Evaluation to the extent of 20% of the theory marks in each course will be based on Internal Assessment. The Board of Control will decide mode of Internal Assessment.
DETAILS OF TEXT AND SYLLABI

SEMESTER –I

Stat-101: LINEAR ALGEBRA (4 Credits)
Final Examination : 80 Marks
Internal Assessment: 20 Marks

Objective: Techniques of linear algebra useful in various Statistics courses will be covered in this course. After learning this course, the students will be well equipped to apply these techniques in many major Statistics courses like Linear Inference, Multivariate Analysis and Operations Research etc.

Note:- The question paper will consist of eight questions carrying equal marks. A candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

Review of basic notions of vector spaces; Subspaces.


Linear Transformations: Kernel and range, inverse transformations, matrices of linear transformations. Change of basis, similarity.


Eigenvalues and eigenvectors: Cayley Hamilton Theorem, diagonalization, triangularization, unitary diagonalization. Spectral theorem for normal matrices.

Jordan decomposition and singular value decomposition of matrices (only methods and not proofs). Generalized inverse: Definition and its computation. Perron’s and Frobenius Theorems (only statement) and their applications.

Quadratic forms: Definite and semi definite quadratic forms, index and signatures, simultaneous diagonalization of symmetric matrices (equivalent quadratic forms), extrema of quadratic forms.

Books:

Additional References:

Note: The contents of this course are as per the scope of C. R. Rao Book.
Stat-102 : DISTRIBUTION THEORY (4 Credits)

Final Examination : 80 Marks
Internal Assessment : 20 Marks

Objective: This course will lay the foundation to probability theory and Statistical modeling of outcomes of real life random experiments through various Statistical distributions.

Note:- (i) The question paper will consist of eight questions carrying equal marks. A candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

(ii) Additional two hours workload per week will be allocated to this course in the afternoon for problem solving.


REFERENCES:


ADDITIONAL REFERENCES:

Objective: The objective of the course is to make the students conversant with various techniques used in summarization and analysis of data. The focus will be both on theoretical as well as practical approach using commonly used Statistical Software.

Note:- (i) The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

(ii) The Practical question paper shall consist of five questions and a candidate will be required to attempt any three questions in four hours duration.

Descriptive Statistics: Meaning, need and importance of statistics. Attributes and variables. Measurement and measurement scales. Collection and tabulation of data. Diagrammatic representation of frequency distribution: histogram, frequency polygon, frequency curve, ogives, stem and leaf plot, pie chart. Measures of central tendency, dispersion (including box and whisker plot), skewness and kurtosis. Data on two attributes, independence and association of attributes in 2x2 tables. Linear regression and correlation (Karl Pearson’s and Spearman’s) and residual plots.


Index Numbers: Meaning of index number. Problems in construction of index numbers: purpose of the index, choice of base period, choice of commodities, choice of weights, interpretation of the index. Laspeyer’s, Paasche’s and Fisher’s index numbers. Errors in index numbers, tests for index numbers, cost of living index numbers. Uses of index numbers (real wages, splicing and deflating).


Sampling distributions: Normal, Chi-square, t, and F distributions and their relations. Population, random sample, parameter, statistic and sampling distribution. Sample mean and sample variance associated with a random sample from a normal distribution: their independence, sampling distributions, expectations and standard errors.

Tests of Significance: Statistical hypotheses, type I and II errors, level of significance, test of significance, concept of p-value. Tests of significance for the parameters of normal distribution (one sample and two sample problems) and the relevant confidence intervals. Chi-square test of goodness of fit and independence of attributes. Test of significance for correlation coefficient. ($\rho = 0$, $\rho = \rho_0$).

Use of Statistical packages: Topics should include graphic representation of data, descriptive statistics, simple hypothesis tests, correlation and linear regression.

REFERENCES:


**ADDITIONAL REFERENCES:**


SEMESTER- II

Stat-201: STATISTICAL COMPUTING USING FORTRAN

(Theory 1/2, Practical 1/2)

(4 credits)

Theory Final Examination : 40 Marks
Theory Internal Assessment : 10 Marks
Practical : 50 Marks

Objective: This course is divided in two parts i.e. Numerical Analysis and FORTRAN. First part of the course is about the study of numerical algorithms for mathematical calculations using computers. It contains algorithms for solving transcendental and polynomial equations, system of linear Algebraic equations, interpolation, extrapolation, numerical differentiation and integration. Second part introduces programming language - FORTRAN 77. Students learn to implement numerical methods being studied in theory using FORTRAN 77 on computers.

Note:-
(i) Theory question paper of the final examination will consist of eight questions from numerical analysis only. Various questions will carry equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus of numerical analysis only with no internal choice.

(ii) The practical marks will be based entirely on internal assessment.

Computer system concepts: Computer system components and functions. The central processing unit, Main memory, Bit, Byte, Input/Output Devices, Speeds and memory capacities in computer systems.

Software concepts: Overview of operating systems, types and functions of operating system, application software, overview of existing software packages on Word Processing and Spreadsheets.

FORTRAN-77: Data types and constants, variable names, arithmetic and logical statements, control statements, logical IF, arithmetic IF, block IF, Do loops, unconditional GOTO, Computed GOTO statements. Arrays, character handling, intrinsic functions, statement functions and subroutines. File handling, equivalence, COMMON and DATA statements.

The purpose of this language is to write the program for solving various numerical problems in this course.

NUMERICAL ANALYSIS


Interpolation and approximation: Lagrange & Newton interpolations, finite difference operators, interpolating polynomial using finite differences (Gregory Newton Forward and Backward difference interpolation, Stirling and Bessel interpolations, Hermite interpolation), bivariate interpolation (Lagrange bivariate interpolation, Newton's bivariate interpolation for equispaced points). Approximation (Weierstrass approximation). First order difference equations, linear difference equations with constant coefficients.


REFERENCES:


ADDITIONAL REFERENCES:


Stat-202 : ESTIMATION AND TESTING OF HYPOTHESES (4 Credits)
(Theory 3/4, Practical 1/4)

Objective: The objective of the course is to provide a systematic account of Neyman-Pearson theory of testing and closely related theory of point estimation and confidence sets, together with their applications.

Note:- (i) The question paper will consist of eight questions carrying equal marks. The first question will be compulsory and it will contain short answer type questions covering the whole syllabus with no internal choice. A candidate will be required to attempt five questions, including the first compulsory question, in three hours duration.

(ii) The Practical question paper will consist of five questions. A candidate will be required to attempt any three questions in four hours duration.


Tests of Hypotheses: Concepts of critical regions, test functions, two kinds of errors, size function, power function, level of significance. MP and UMP tests in a class of size $\alpha$ tests. Neyman - Pearson Lemma, MP test for simple null against simple alternative hypothesis. UMP tests for simple null hypothesis against one-sided alternatives and for one-sided null against one-sided alternatives in one parameter exponential family. Extension of these results to Pitman family when only upper or lower end depends on the parameter and to distributions with MLR property. Non-existence of UMP test for simple null against two-sided alternatives in one parameter exponential family. Likelihood Ratio Tests. Wald’s SPRT with prescribed errors of two types.

Interval estimation: Confidence interval, confidence level, construction of confidence intervals using pivots, shortest expected length confidence interval, uniformly most accurate one sided confidence interval and its relation to UMP test for one sided null against one sided alternative hypotheses. Tests of hypotheses and interval estimation viewed as decision problems with given loss functions.

REFERENCES:

ADDITIONAL REFERENCES:
Objective: The objective of this course is to acquaint the students about: (i) the need & merits of sampling over census and (ii) the implementation of various sampling schemes along with their merits, demerits and comparisons in appropriate practical situations, (iii) role of various statistical organizations in national development.

Note:-  
(i) The question paper will consist of eight questions with the following division:
   (a) First question will be compulsory covering the entire syllabus.
   (b) Section-I : This section will have five questions from UNIT-I of the syllabus.
   (c) Section-II : This section will have two questions from UNIT-II of the syllabus.

The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

A candidate is required to attempt five questions in all, in three hours duration, including first compulsory question, selecting three questions from Section-I and one question from Section-II.

(ii) The Practical question paper shall consist of five questions and a candidate will be required to attempt any three questions in four hours duration.

UNIT-I


Ratio and regression estimators based on SRSWOR method of sampling. Two-stage sampling with equal size of first stage units. Double sampling for ratio and regression methods of estimation. Cluster sampling - equal clusters.

Unequal probability sampling: PPS WR/WOR methods [cumulative total, Lahiri’s schemes] and related estimators of a finite population mean [Thompson-Horwitz, Yates and Grundy estimator, Desraj estimators for a general sample size and Murthy’s estimator for a sample of size 2].

UNIT-II

National sample surveys organization (NSSO) and role of various statistical organizations in national development. Scope and contents of population census in India. Review of national income and their estimates.

REFERENCES:

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<th>Reference</th>
<th>Details</th>
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<tr>
<td></td>
<td>University Press &amp; IARS.</td>
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**ADDITIONAL REFERENCES:**

<table>
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<tr>
<th>Reference</th>
<th>Details</th>
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<tbody>
<tr>
<td></td>
<td>International Publishers.</td>
</tr>
<tr>
<td>3. R.G. Lipsey</td>
<td>Introduction to Positive Economics (Chapter-32)</td>
</tr>
</tbody>
</table>
Objective: The objective of this course is to apprise the students about various techniques of hypothesis testing when the assumptions of parametric set up are not fulfilled. Thrust will be to study various nonparametric analogues to one, two and c-sample location problems as well as two sample scale problem.

Note:- (i) The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

(ii) The Practical question paper shall consist of five questions and a candidate will be required to attempt any three questions in four hours duration.

Estimable parametric functions, kernel, symmetric kernel, one sample U-Statistic. Two sample U-Statistic, asymptotic distribution of U-Statistics, UMVUE property of U-Statistics.

Empirical distribution function, confidence intervals based on order statistics for quantiles, tolerance regions.


Tests for the c-sample problem: Kruskal-Wallis, Jonckheere- Terpstra tests.

Concepts of Jackknifing, method of Quenouille for reducing bias, Bootstrap methods.

REFERENCES:

ADDITIONAL REFERENCES:
Stat-302: STATISTICAL PROCESS AND QUALITY CONTROL (4 Credits)
(Theory 3/4, Practical 1/4)

Theory Final Examination : 60 Marks
Theory Internal Assessment : 15 Marks
Practical : 25 Marks

Objective: The paper shows the applications of Statistics to maintain quality in Engineering or industrial set up. The theory of control charts, sampling plans and process capability indices is the basis for judging whether the process is in statistical control or not. The topics are quite helpful during industrial training/placements of M.Sc. Students.

Note:- (i) The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.
(ii) The Practical question paper shall consist of five questions and a candidate will be required to attempt any three questions in four hours duration.

The meaning of quality, quality assurance, technology and productivity. Statistical methods for quality control and improvement.

Chance and assignable causes of quality variation, general theory of control charts, control charts for variables: \( \bar{X} \) and R chart, analysis of pattern on control charts, control chart for attributes- np, p, c and u charts. Multiple stream processes: Group control charts. Specification limits and tolerance limits.

Process capability analysis, introduction, Capability indices- \( C_p \), \( C_{pk} \) and \( C_{pm} \). Estimation, confidence intervals and tests of hypotheses relating to capability indices for normally distributed characteristics.


Acceptance Sampling plans for attribute inspection: Single, double and sequential sampling plans and their properties, including OC, AOQL and ASN curves. Plans for inspection by variables for one-sided and two-sided specifications. Specification of sampling plan by LTPD and AOQL. Mill Std plans, Dodge and Roming tables.

REFERENCES:


ADDITIONAL REFERENCES:

Stat 303: LINEAR INFERENCE
(Theory 3/4, Practical 1/4) (4 Credits)
Theory Final Examination : 60 Marks
Theory Internal Assessment : 15 Marks
Practical : 25 Marks

Objective: The students will get familiar with the need of modeling random responses using independent predictors through linear and logistic (for binary responses) models in real life situations. Least square estimation of parameters of these models will be discussed along with their statistical significance.

Note:- (i) The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.
(ii) The Practical question paper shall consist of five questions and a candidate will be required to attempt any three questions in four hours duration.


Introduction to Estimation: Point and interval estimates, best linear unbiased estimates, construction of confidence intervals of the parameters of linear model.

Theory of Least Squares and Analysis of Variance: Gauss-Markoff set-up, normal equations, least squares estimates and their precision, use of g-inverse, statements and applications of fundamental theorems of least squares.

Introduction to fixed, mixed and random effect models. Tests of significance and interval estimates based on least squares theory in one-way and two-way classified data, a general model for two-way data, Bartlett test for testing of homogeneity of variances.


REFERENCES:
1. C.R. Rao (2002) : Linear Statistical Inference and its Applications, 2nd Ed., Wiley, Chapters: 3b, 3c, 3d, 4a to 4e, 4f.1, 4g.1, 4g.3, 4g.4, 4h.

ADDITIONAL REFERENCES:
Stat-401: MULTIVARIATE ANALYSIS
(Theory 3/4, Practical 1/4)

Objective: The course deals with the statistical estimation and testing problems when the underlying structure is not univariate but multivariate in nature. Various multivariate techniques (estimation and testing) required to handle two or more correlated response variables, will be discussed under multivariate normal setting. One sample, two sample and c-sample multivariate normal mean vector testing problems will be discussed.

Note:- (i) The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

(ii) The Practical question paper shall consist of five questions and a candidate will be required to attempt any three questions in four hours duration.


Null distribution of partial and multiple correlation coefficient. Application in testing and interval estimation.

Null 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. Mahalanobis $D^2$ and its sampling distribution.

Wishart distribution and its properties. Distribution of sample generalized variance. Classification and discriminant procedure for discriminating between two multivariate normal populations, Sample discriminant function and tests associated with discriminant functions, probabilities of misclassification and their estimation.


Principle components, dimension reduction, canonical variables and canonical correlation: definition, use, estimation and computation.

REFERENCES:

ADDITIONAL REFERENCES:
Objective: To provide orientation of statistics while designing statistical experiments, particularly in agricultural set up and in pharmaceutical production processes. Exposure to various statistical designs leading to the analysis of variance, eliminating heterogeneity of the data, construction of designs will be provided.

Note: (i) The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

(ii) The Practical question paper shall consist of five questions and a candidate will be required to attempt any three questions in four hours duration.

Three basic principles of design of experiments: Randomisation, replication and local control. Design useful for one-way elimination of heterogeneity. Completely randomised, randomised complete block and balanced incomplete block designs. Concepts of balancing, orthogonality, connectedness and properties of C-matrix. General inter and intra block analysis of incomplete block designs, $2^k, 2^3, 3^2$ and $3^3$ factorial designs, fractional replication and split-plot designs. Design useful for two-way elimination of heterogeneity and their general method of analysis by using fixed effect model, Latin squares, Graeco Latin squares and Youden squares designs.

Missing plot techniques, illustrations of construction of $s \times s$ mutually orthogonal Latin squares and balanced incomplete block designs (by using finite geometries, symmetrically repeated differences and known B.I.B. designs).

REFERENCES:

1. O.Kempthorne (2007) : Design and Analysis of Experiments, Wiley

ADDITIONAL REFERENCES:

M 1: ACTUARIAL STATISTICS (4 Credits)

Final Examination : 80 Marks
Internal Assessment : 20 Marks

Objective: The objective of the course is to provide the students with a foundation into the applications of Statistics and Probability for important calculations in insurance, pension plans and other investment areas. Statistical methods help in dealing with uncertain risks faced by the people. Laws of probability are used for estimation of possible losses to the insured person. Life insurance premiums are mainly based on Statistical tables called mortality/life tables. Expertise in Actuarial Statistics is globally appreciated and provides opportunities for employment in insurance and financial sector. Students with a degree in Statistics and adequate background in actuarial science are in great demand internationally and are highly paid.

Note: The question paper will consist of eight questions carrying equal marks. The first question will be compulsory containing short answer type questions covering the entire syllabus and with no internal choice. Section-I will have four questions on Probability models and Life Tables and Section-II will have three questions on Insurance and Annuities. A candidate will be required to attempt five questions in three hours duration, including the first compulsory question and selecting at least two from Section-I and at least one from Section–II.

Section I–Probability Models and Life Tables

Loss distributions: Modelling of individual and aggregate losses, moments, fitting distributions to claims data, deductibles and retention limits, proportional and excess-of-loss reinsurance.

Risk models: Models for individual claims and their sums, Distribution of aggregate claims, Compound distributions and applications.
Introduction to credibility theory.
Survival function, curtate future lifetime, force of mortality.
Multiple life functions, joint life and last survivor status.
Multiple decrement model.

Section II –Life Contingencies:

Principles of Compound Interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor.

Assurance and Annuity Contracts: Definitions of benefits and premiums, various types of assurances and annuities, present value, formulae for mean and variance of various continuous and discrete payments.

Calculation of various payments from life tables: Principle of equivalence, net premiums, prospective and retrospective provisions/reserves.
REFERENCES:


   Science, Chapman and Hall/CRC
   interdisciplinary Statistics.

   Basel.


ADDITIONAL REFERENCES:

1. Dickson D.C.M., Hardy : Actuarial Mathematics for Life Contingent

   University Press
M 2 : CATEGORICAL DATA ANALYSIS

Objective: This course deals with the analysis of categorical data measured on different scales. The estimation and testing techniques related to various advance models are discussed. Fitting of models and strategies in model selection are also discussed.

Note: The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

Categorical response variables: Nominal, ordinal, interval Categorical data describing two-way contingency tables, measures of nominal and ordinal association, inference for two-way contingency tables, likelihood functions and maximum likelihood estimates, testing goodness of fit and testing independence. Screening tests, sensitivity, specificity, and predictive value positive and negative, partitioning chi-squared, large sample confidence intervals, delta method to estimate standard error, exact tests for small samples.

Models for binary response variables: Generalized linear models, logit, log linear, linear probability and logistic regression models. Logit models for categorical data, probit and extreme value models, models with log-log link, model diagnostics.


REFERENCES:


ADDITIONAL REFERENCES:

M 3: ECONOMETRICS

Objective: This course introduces the theory and applications of econometrics: the application of statistical methods to economic data. Many of the methods introduced in this course are also used in business, finance and many other disciplines. The course includes a review of probability theory, mathematical expectation and theoretical probability distribution. Modeling techniques are also utilized for hypothesis testing and economic forecasting. We will learn how to construct econometric models, estimate the parameters of those models and interpret the parameter estimates.

Note: The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

Nature of econometrics. The general linear model (GLM) and its assumptions. Ordinary least squares (OLS) estimation and prediction. Significance tests and confidence intervals, linear restrictions. Use of dummy variables and seasonal adjustment. Generalized least squares (GLS) estimation and prediction. Heteroscedastic disturbances.


Estimation in simultaneous equations model. Recursive systems. 2 SLS estimators, k-class estimators. 3SLS estimation. Full information maximum likelihood method. Prediction and simultaneous confidence intervals. Monte Carlo studies and simulation.

REFERENCES:


ADDITIONAL REFERENCES

M 4: ECONOMIC STATISTICS

Final Examination : 80 Marks
Internal Assessment: 20 Marks

Objective: The objective of this course is to acquaint students with the basic concepts of Microeconomic theory and the analysis of Statistical concepts used in the context of economic set up.

Note:- The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

Introduction to Economic Science.
1. **The Theory of Consumer Behaviour**: Utility function, indifference curves and their properties, price and income elasticities, substitution and income effects.
5. Inequality of income, Gini coefficient, Lorenz curve mathematically & its deviation for some well-known income distribution function.

REFERENCES:
M 5: ADVANCED INFERENCE
(Theory 3/4, Practical 1/4) (4 Credits)

Objective: The objective of this paper is to acquaint students with the advanced applications of statistical inference along with the higher probability concepts. The course lays the background for the students to get familiar with the properties of various estimators used in inference.

Note:- (i) The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.
(ii) The Practical question paper shall consist of five questions and a candidate will be required to attempt any three questions in four hours duration.

Review of convergence in probability and convergence in distribution, Cramer and Slutsky’s Theorems.
Consistent Estimation of real and vector valued parameters. Invariance of Consistent estimator under continuous transformation, consistency of estimators by method of moments, and method of percentiles, mean squared error criterion, asymptotic relative efficiency, error probabilities and their rates of convergence. Minimum sample size required to attain given level of accuracy.
Consistent Asymptotic Normal (CAN) estimator, invariance of CAN estimator under differentiable transformation, CAN property of estimators obtained by moments and percentiles, CAN estimators obtained by moment and MLE method in one parameter exponential family, extension to multi-parameter exponential family, examples of consistent but not asymptotically normal estimators from Pitman family. Method of maximum likelihood, CAN estimators for one-parameter Cramer family, Cramer – Huzurbazar theorem. Solution of likelihood equations, method of scoring, Newton – Raphson and other iterative procedures, Fisher Lower bound to asymptotic variance, extension to multi-parameter case (without proof). Multinomial distribution with cell probabilities depending on a parameter.
MLE in Pitman family and double exponential distribution, MLE in censored and truncated distributions.
Likelihood Ratio Test (LRT), asymptotic distribution of LRT statistic, Wald test, Rao’s score test, Pearson’s chi-square test for goodness of fit, Bartlett’s test for homogeneity of variances. Large sample tests and confidence intervals based on CAN estimators, variance stabilizing transformation and large sample tests. Consistency of large sample tests, asymptotic power of large sample tests.

REFERENCES:

ADDITIONAL REFERENCES:
M 6 : MEASURE & PROBABILITY THEORY (4 Credits)

Final Examination: 80 Marks
Internal Assessment: 20 Marks

Objective: Measure Theory is an essential area of Mathematics for analysis of probability models. In fact, measure theory is a basic requirement for Kolmogrov probability model. This course is a brief introduction to measure theory and its first application to probability theory.

Note:- The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

Measure Theory: Classes of sets, fields, sigma-fields, minimal sigma-field, Borel sigma-field in $\mathbb{R}^k$. Measure, probability measure, properties of a measure, Caratheodory extension theorem (statement only), Lebesgue and Lebesgue- Stieljes measures on $\mathbb{R}^k$.

Probability Theory: Measurable functions, Random variables, sequence of random variables. Limit Supremum & limit infimum, Borel contelli Lemma. Almost sure convergence, convergence in probability (and in measure). Integration of a measurable function with respect to a measure, Fatou’s Lemma, Monotone convergence theorem. Convergence in distribution, characteristic function, uniqueness theorem, inversion theorem (statement and applications only), Levy’s continuity theorem (statement only), CLT for a sequence of independent random variables under Lindeberg’s condition, CLT for iid random variables.

REFERENCES:


ADDITIONAL REFERENCES:

M 7: OPERATIONS RESEARCH                                  (4 Credits)

Theory Final Examination     : 60 Marks
Theory Internal Assessment  : 15 Marks
Practical                                   : 25 Marks

Objective: Operations Research deals with the application of scientific methods and techniques to decision-making problems. A decision-making problem occurs where there are two or more alternative courses of action, each of which leads to a different and sometimes unknown end result. Operations research is also used to maximize the utility of limited resources. The objective is to select the best alternative, that is, the one leading to the best result. It has applications in the management and administration of military, government, commercial, and industrial systems. It also helps in resource allocation and replacement, inventory control and scheduling of large-scale construction projects.

Note:-
(i) The question paper will consist of eight questions carrying equal marks. The first question will be compulsory containing short answer type questions covering the entire syllabus and with no internal choice. The candidate will be required to attempt five questions including the first compulsory question in three hours duration.

(ii) The Practical question paper shall consist of five questions and a candidate will be required to attempt any three questions in four hours duration.

Origin and development of operations research (O.R.), modelling in O.R., applications of O.R., opportunities and shortcomings of O.R.

Formulation of linear programming problem (LPP), graphical solution to LPP, properties of a solution to the (LPP), generating extreme point solutions. The simplex computational procedure, development of minimum feasible solution, a first feasible solution using slack variables, the artificial basis technique. Two phase method and Charnes M-method with artificial variables. The duality problem of linear programming and its economic interpretation, transportation and assignment problems. Sensitivity analysis, network flow problem. Game theory problem as a linear programming problem, integer programming.

Replacement models & sequencing theory, inventory models with single and multiple periods.

REFERENCES:

ADDITIONAL REFERENCES:
M 8: REAL & COMPLEX ANALYSIS

Final Examination : 80 Marks
Internal Assessment : 20 Marks

Subject: This course provides help to understand the mathematical concept of convergence and its mathematical formalisms. Students will be able to use some fundamental theorems of mathematical analysis. Students will have knowledge of the special character of functions of a complex variable and their properties during this course.

Note: The question paper will consist of nine questions carrying equal marks. The first question will be compulsory containing short answer type questions covering the entire syllabus and with no internal choice. Section-I will have five questions on Real Analysis and Section-II will have three questions on Complex Analysis. A candidate will be required to attempt five questions in three hours duration, including the first compulsory question and selecting at least two questions from Section-I and at least one question from Section – II.

SECTION-I
Sequence of sets, limit sup and limit inf of a sequence of sets. Countable and uncountable sets, open and closed intervals (rectangles), compact sets, Bolzano-Weierstrass theorem (statement only). Heine – Borel theorem (statement only). Properties of continuous functions on compact sets.


Fourier series of a function relative to an orthogonal system of functions, convergence of Fourier series to its defining functions.

SECTION-II
Complex Numbers, geometrical representation of complex numbers, functions of a complex variable, differentiability and analyticity, Cauchy-Riemann conditions.

Elementary, exponential and logarithmic functions.

Power series, radius of convergence, differentiation of a power series, Taylor’s and Laurent’s series, Residues. Integration of a function of a complex variable, Cauchy’s theorem and Cauchy’s Integral theorem (Statement and applications only).

Applications of Residues: Evaluation of definite and improper integrals.

REFERENCES:

2. Shanti Narayan (1973) : A Course of Mathematical Analysis, 10th Revised Edition

ADDITIONAL REFERENCES:

M 9: RELIABILITY

(4 Credits)

Final Examination : 80 Marks
Internal Assessment: 20 Marks

Objective: This course covers the main statistical methods used in reliability and life data analysis. The main distributions used in reliability data analysis are overviewed. The ageing properties of different distributions are explored. A course in reliability helps in probabilistic modeling of the reliability of systems with multiple components and statistical modeling of reliability of individual components based on lifetime data.

Note: The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

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

Life distributions and associated survival, conditional survival and hazard rate functions. Exponential, Weibull, gamma life distributions and estimation of their parameters.

Notions of ageing. IFR IFRA, NBU, DMRL, NBUE, and HNBUE classes; their duals and relationships between them. Closures of these classes under formation of coherent systems, convolutions and mixtures.

Partial orderings: Convex, star, stochastic, failure rate and mean-residual life orderings. Univariate shock models and life distributions arising out of them.

Maintenance and replacement policies, availability of repairable systems.

REFERENCES:


ADDITIONAL REFERENCES:

M 10: SIMULTANEOUS INFEERENCE  

(4 Credits)

**Final Examination : 80 Marks**

**Internal Assessment: 20 Marks**

**Objective:** Demoralization of two sample problems to multi-sample (k-sample) problem, testing of related several hypotheses simultaneously at a pre-specified level and construction of simultaneous confidence intervals at a pre-specified confidence level for various parametric functions are the main objective of the course.

**Note:-** The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

Introduction to simultaneous inference, error rates, Bonferroni inequality, p-mean significance levels, basic techniques of multiple comparisons and their geometrical interpretation for the case of two means.

Studentized range, Scheffe’s F-projections, Bonferroni t-statistics, studentized maximum modulus, many-one t-statistics, Duncan’s multiple range test, Newman-Keuls test, Fisher’s LSD test, Tukey’s gap-straggler-variance test, two-sample confidence intervals of predetermined length, and improved Bonferroni inequality.

Many-one sign statistics, k-sample sign statistics, many-one rank statistics, k-sample rank statistics, signed-rank statistics, Kruskal-Wallis rank statistics, Friedman rank statistics, and permutation test.

**Multivariate techniques:** Single population with covariance scalar unknown, single population with covariance matrix unknown.

**REFERENCES:**

1. R.G. Miller (Jr.) : Simultaneous Statistical Inference, Springer-Verlag, Chapters 1, 2, 4, 5 (Sections 5.1 and 5.2)


**ADDITIONAL REFERENCES:**


M 11 : STATISTICAL SIMULATION AND COMPUTATION
(Theory 1/2, Practical 1/2) (4 Credits)

Theory Final Examination : 40 Marks
Theory Internal Assessment : 10 Marks
Practical : 50 Marks

Objective: This course is divided into three parts i.e. Simulation, ‘C’ Programming Language and Pattern Recognition. First part of the course is about the study of Simulation using Computers. It contains introduction to System, Models, Simulation, Random Number Generation and Variance Reduction Techniques. Second part introduces programming language ‘C’ on Computers. Third part is an introduction to Pattern Recognition and Students are encouraged to give seminars from this topic.

Note:- (i) The Theory question paper of the final examination will consist of eight questions from Simulation only. Various questions will carry equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

(ii) The practical marks will be based entirely on internal assessment.

Introduction Function to C: Data types, operator and expressions, Input/Output statement, control statement, functions, Arrays, Structures.


Random Number Generation: Congruential generators, statistical tests for pseudo random numbers.


Monte Carlo integration and variance reduction techniques: Hit or miss Monte Carlo method, sample mean Monte Carlo method, importance sampling, correlated sampling control variates, stratified sampling, antithetic variates, partition of region.

Introduction to Pattern Recognition: Pattern classification by likelihood functions.

REFERENCES:

ADDITIONAL REFERENCES:
M 12: STOCHASTIC PROCESSES  
(4 Credits)  

Objective: The main objective of this course is to apprise the students about the existence of several stochastic processes in real life situations and to equip them with the techniques to study their statistical behaviour as a sequence of dependent random variables.

Note:- The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.


Discrete state space continuous time Markov Processes; Wiener process, Kolmogorov- Feller differential equations, Poisson process, birth and death processes.

Renewal theory: Renewal process, elementary renewal theorem and applications. Statement and uses of key renewal theorem, study of residual lifetime process.

Branching process: Galton-Watson branching process, probability of ultimate extinction, distribution of population size.

REFERENCES:


ADDITIONAL REFERENCES:

M 13: SURVIVAL ANALYSIS (4 Credits)

Objective: The course gives the application of statistics in handling survival data. The course introduces the concept of censoring and the various distributions used to analyse such data. Various models are also suggested to deal with survival data.

Note:- The question paper will consist of eight questions carrying equal marks. The candidate will be required to attempt five questions including the first compulsory question in three hours duration. The compulsory question shall contain short answer type questions covering the whole syllabus with no internal choice.

Concepts of Type-I (time), Type-II (order) and random censoring likelihood in these cases. Life distributions, exponential, gamma, Weibull, lognormal, Pareto, linear failure rate. Inference for exponential, gamma, Weibull distributions under censoring.

Failure rate, mean residual life and their elementary properties. Ageing classes and their properties, bathtub failure rate.

Estimation of survival function – Actuarial estimator, Kaplan – Meier estimator, Tests of exponentiality against non-parametric classes: Total time on Test, Deshpande Test.

Two sample problem: Gehan test, Log rank test. Mantel-Haenszel test, Cox’s proportional hazards model, competing risks model.

REFERENCES:

ADDITIONAL REFERENCES:

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