CURRICULUM
OF
STATISTICS
BS/MS

(Revised 2013)
CURRICULUM DIVISION, HEC

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Mr. Fida Hussain  Director General (Acad)
Mr. Rizwan Shoukat  Deputy Director (Curr)
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Composed by: Tanveer Ali, HEC, Islamabad
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PREFACE

The curriculum, with varying definitions, is said to be a plan of the teaching-learning process that students of an academic programme are required to undergo. It includes objectives & learning outcomes, course contents, scheme of studies, teaching methodologies and methods of assessment of learning. Since knowledge in all disciplines and fields is expanding at a fast pace and new disciplines are also emerging; it is imperative that curricula be developed and revised accordingly.

University Grants Commission (UGC) was designated as the competent authority to develop, review and revise curricula beyond Class-XII vide Section 3, Sub-Section 2 (ii), Act of Parliament No. X of 1976 titled “Supervision of Curricula and Textbooks and Maintenance of Standard of Education”. With the repeal of UGC Act, the same function was assigned to the Higher Education Commission (HEC) under its Ordinance of 2002, Section 10, Sub-Section 1 (v).

In compliance with the above provisions, the Curriculum Division of HEC undertakes the revision of curricula after every three years through respective National Curriculum Revision Committees (NCRCs) which consist of eminent professors and researchers of relevant fields from public and private sector universities, R&D organizations, councils, industry and civil society by seeking nominations from their organizations.

In order to impart quality education which is at par with international standards, HEC NCRCs have developed unified templates as guidelines for the development and revision of curricula in the disciplines of Basic Sciences, Applied Sciences, Social Sciences, Agriculture and Engineering in 2007 and 2009.

It is hoped that this curriculum document, prepared by the respective NCRC’s, would serve the purpose of meeting our national, social and economic needs, and it would also provide the level of competency specified in Pakistan Qualification Framework to make it compatible with international educational standards. The curriculum is also placed on the website of HEC (www.hec.gov.pk).

(Fida Hussain)
Director General (Academics)
CURRICULUM DEVELOPMENT PROCESS

STAGE-I
- CURRI UNDER CONSIDERATION
  - COLLECTION OF REC
  - CONS. OF CRC.
  - PREP. OF DRAFT BY CRC

STAGE-II
- CURRI IN DRAFT STAGE
  - APPRAISAL OF 1ST DRAFT BY EXP. OF COL./UNIV
  - FINALIZATION OF DRAFT BY CRC
  - APPROVAL OF CURRI. BY V.C.C.

STAGE-III
- FINAL STAGE
  - PREP. OF FINAL CURRI.
  - INCORPORATION OF REC. OF V.C.C.

STAGE-IV
- FOLLOW UP STUDY
  - QUESTIONNAIRE
  - COMMENTS
  - PRINTING OF CURRI.
  - REVIEW
  - IMPLE. OF CURRI.
  - BACK TO STAGE-I
  - ORIENTATION COURSES

Abbreviations Used:
- CRC. Curriculum Revision Committee
- VCC. Vice Chancellor’s Committee
- EXP. Experts
- COL. Colleges
- UNI. Universities
- PREP. Preparation
- REC. Recommendations
INTRODUCTION

MINUTES OF THE FINAL MEETING OF HEC NATIONAL CURRICULUM REVISION COMMITTEE ON STATISTICS HELD AT RC PESHAWAR FROM APRIL 22-24, 2013

The final meeting of National Curriculum Revision Committee (NCRC) in the discipline of Statistics was held from April 22-24, 2013 at HEC Regional Centre, Peshawar to finalize draft curriculum of Bachelor Studies (BS) and Master Studies (MS) programme in Statistics, developed in preliminary meeting held at Karachi. The following members attended the meeting:-

1. Prof. Dr. Salahuddin
   Convener
   Department of Statistics
   University of Peshawar, Peshawar.

2. Prof. Dr. Ejaz Ahmed
   Department of Computer Science
   Institute of Business Management, Karachi.

3. Prof. Dr. Mir Ghulam Hyder Talpur
   Department of Statistics
   University of Sindh, Jamshoro.

4. Syed Anwer Hasnain,
   Associate Professor,
   Department of Statistics,
   National College of Business Administration & Economics, Lahore.

5. Dr. Irshad Ahmad Arshad
   Associate Professor/Chairman
   Department of Mathematics & Statistics
   International Islamic University, Islamabad.

6. Dr. Saleha Naghmi Habibullah
   Associate Professor
   Department of Statistics, Kinnaird College for Women, Lahore.

7. Mr. Munawar Iqbal
   Assistant Professor
   College of Statistical & Actuarial Sciences,
   University of the Punjab, Lahore.

8. Dr. Amjad Ali
   Lecturer,
   Department of Statistics, Islamia College, Peshawar.

9. Dr. Bahrawar Jan
   Deputy Director General, Pakistan Bureau of Statistics, Islamabad.

10. Dr. Muhammad Azam,
    Associate Professor
    Department of Statistics, Forman Christian College, Lahore.
The meeting started with the recitation of Holy Quran by Mr. Abid Wahab. Mr. Zaheer Ahmed Awan, Director RC Peshawar, HEC on behalf of the Chairperson and the Executive Director, HEC welcomed the participants and thanked all the members of the Committee for sparing precious time for this national cause. He briefed the participants on the aim and objectives of the meeting with a particular focus on revising the course outlines of BS (4-year) and also developing the course outlines of MS Programme in Statistics so as to make it compatible with international standards and demands as well as ensuring the uniformity of academic standard within the country.

Mr. Riaz-ul-Haque then requested the Convener of the Committee to conduct proceedings of all technical sessions of the meeting for three days. **Dr. Salahuddin**, Professor, Department of Statistics, University of Peshawar, Peshawar as **Convener** and **Dr. Faisal Maqbool Zahid**, Assistant Professor, Department of Statistics, Government College University, Faisalabad as **Secretary** NCRC, thanked the participants for
their participation and started proceedings of the meeting in accordance with the agenda.

4. The Committee reviewed and discussed the draft curriculum of BS Statistics, prepared in preliminary meeting and considered the inputs given by the members of NCRC & after detailed discussion; the Committee incorporated their suggestions in the draft curriculum. The Committee also discussed the agenda item regarding development of Scheme of MS Statistics degree programme and it was concluded that as per HEC policy and international standards credit hours for MS would be 30 credit, 24 credit hours for courses and 6 credit hours for research work.

5. After thorough and three days deliberations the committee unanimously approved the final draft curriculum of the BS and MS Statistics degree programmes which was prepared in the preliminary meeting of NCRC.

The Committee during its deliberation achieved the following objectives:

1. Reviewed and finalized the draft curriculum for Bachelor Studies (BS) and Master Studies (MS) in the discipline of Statistics so as to bring it at par with international standards.
2. Incorporated latest reading & writing material against each course.
3. Brought uniformity and developed minimum baseline courses in each and every course of study.
4. Made recommendations for promotion/development of the discipline.

6. The Convener of the NCRC, Prof. Dr. Salahuddin thanked all the members for their valuable inputs in finalizing the revised curriculum keeping in view the requirement of the country and to make it more practical competitive and effective. He appreciated for their dedication and hard work in this task of national importance. The Committee highly
appreciated the efforts made by the officers of HEC and all of other officials of HEC Regional Centre, Peshawar for providing local hospitality.

7. Mr. Abid Wahab & Mr. Riaz-ul-Haque, Assistant Directors, HEC thanked the Convener and all the members of the Committee on behalf of Mr. Farman Ullah Anjum, Director General (Academics), HEC for sparing precious time and for their quality contribution towards preparation of the preliminary draft curriculum in the discipline of Statistics.

8. The meeting ended with vote of thanks to and from the chair.
## FRAME WORK FOR BS (4-YEAR) IN STATISTICS LAYOUT

<table>
<thead>
<tr>
<th>Compulsory Requirements (the student has no choice)</th>
<th>General Courses to be chosen from other departments</th>
<th>Discipline Specific Foundation Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 courses</td>
<td>7-8 courses</td>
<td>9-10 courses</td>
</tr>
<tr>
<td>25 Credit hours</td>
<td>21-24 Cr. Hours</td>
<td>30-33 Credit hours</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Cr Hr</th>
<th>Subject</th>
<th>Cr Hr</th>
<th>Subject</th>
<th>Cr Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. English I</td>
<td>3</td>
<td>1. Introduction to Psychology</td>
<td>3</td>
<td>Introductory Statistics</td>
<td>3</td>
</tr>
<tr>
<td>2. English II</td>
<td>3</td>
<td>2. Introduction to Logic</td>
<td>3</td>
<td>Introduction to Probability &amp; Probability Distributions</td>
<td>3</td>
</tr>
<tr>
<td>4. Communication Skill</td>
<td>3</td>
<td>4. International Relations</td>
<td>3</td>
<td>Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td>5. Pakistan Studies</td>
<td>2</td>
<td>5. Basics of Sociology</td>
<td>3</td>
<td>Introduction to Regression Analysis &amp; Experimental Design</td>
<td>3</td>
</tr>
<tr>
<td>6. Islamic Studies / Ethics</td>
<td>2</td>
<td>6. Introduction to Environmental Sciences</td>
<td>3</td>
<td>Applied Statistics</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9. (Entrepreneurship)</td>
<td>3</td>
<td>Statistical Packages</td>
<td>3</td>
</tr>
<tr>
<td>9. Introduction to Computer</td>
<td>3</td>
<td><strong>OR</strong></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>* from the list of general courses given in Annexure on Page 5</td>
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</tr>
<tr>
<td>TOTAL</td>
<td>25</td>
<td></td>
<td>21</td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>Major courses including research project/internship</td>
<td>Elective Courses within the major</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>-----------------------------------------------------</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-13 courses</td>
<td>4 courses</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>36-42 Credit hours</td>
<td>12 Credit Hours</td>
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</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Cr</th>
<th>Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Regression Analysis</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2. Design &amp; Analysis of Experiment-I</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3. Probability and Probability Distribution-II</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4. Sampling Techniques-II</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5. Econometrics</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>6. Design &amp; Analysis of Experiment-II</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>7. Statistical Inference-1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>8. Multivariate Analysis-I</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>9. Multivariate Analysis-II</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>11. Statistical Inference-II</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>12. Official Statistics</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>13. Research Project / Internship</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>46</td>
<td>12</td>
</tr>
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</table>

OR ** from the list of elective courses.
MODEL SCHEME OF STUDIES FOR BS (4-YEAR) IN STATISTICS

<table>
<thead>
<tr>
<th>Semester / Year</th>
<th>Name of Subject</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First</strong></td>
<td>Introductory Statistics</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pakistan Studies</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>English-I (Functional English)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Calculus-I</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>General-I</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>General-II</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>17</strong></td>
</tr>
<tr>
<td><strong>Second</strong></td>
<td>Introduction to Probability Distributions</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Islamic Studies/Ethics</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>English-II</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Calculus-II</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>General-III</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>General-IV</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>17</strong></td>
</tr>
<tr>
<td><strong>Third</strong></td>
<td>Basic Statistical Inference</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>English-III</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Introduction to Computer</td>
<td>3</td>
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<tr>
<td></td>
<td>General-V</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>General-VI</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>15</strong></td>
</tr>
<tr>
<td><strong>Fourth</strong></td>
<td>Applied Statistics</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Introduction to Regression Analysis &amp; Experimental Design</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Communication Skills</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>General-VII</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>15</strong></td>
</tr>
<tr>
<td><strong>Fifth</strong></td>
<td>Probability Distribution-1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Sampling Technique-I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Design &amp; Analysis of Experiment-I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Regression Analysis</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Statistical Packages</td>
<td>3</td>
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<tr>
<td></td>
<td></td>
<td><strong>18</strong></td>
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<tr>
<td><strong>Sixth</strong></td>
<td>Probability Distribution-II</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Sampling Techniques-II</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Design &amp; Analysis of Experiment-II</td>
<td>4</td>
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<tr>
<td></td>
<td>Credits</td>
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<tr>
<td>Econometrics</td>
<td>4</td>
<td></td>
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<tr>
<td>Official Statistics</td>
<td>3</td>
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<td></td>
<td>18</td>
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<tr>
<td>Seventh</td>
<td></td>
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<tr>
<td>Statistical Inference-1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Applied Multivariate Analysis</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Time Series Analysis</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Elective I</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Elective-II</td>
<td>3</td>
<td></td>
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<td></td>
<td>16</td>
<td></td>
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<tr>
<td>Eight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statistical Inference-II</td>
<td>3</td>
<td></td>
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<tr>
<td>Population Studies</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Research Project / Internship</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Elective-III</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Elective-IV</td>
<td>3</td>
<td></td>
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<tr>
<td></td>
<td>16</td>
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<tr>
<td>Total</td>
<td>132</td>
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</tbody>
</table>

**Note:** 4 credit hours courses must include Lab. /Practical.

**Aims and Objectives**

The major aims and objectives of the curriculum of Statistics are to adapt the curriculum to meet the international standards.

1. To provide a sound footing of the subject matter of statistical theory with applications, so that the students can pursue higher degrees and research in the field of statistics.

2. To train the students in the use of statistical software and techniques of data collection and analysis so that they can compete in the job market.

3. To involve the students in research project so that they can be better trained in the field of research.

4. To develop a solid foundation for the effective operational and strategic decisions based on statistical theory and methodology in almost every discipline.
* LIST OF GENERAL COURSES FOR STATISTICS

Seven courses are to be selected from the following list of courses, according to available facilities and faculty of the universities.

1. Business Administration (Entrepreneurship)
2. Human Resource Management
3. Environmental Sciences
4. Principles of Management & Marketing
5. Basic Financial Management
6. History of Human Civilization
7. Introduction to Biology
8. Foreign Language other than English
9. Introduction to Physics
10. Advanced Calculus
11. Introduction to Genetics
12. Introduction to Geography

or any other subject depending upon the expertise available.

** Elective Courses for BS (4-Year) Programme for Statistics

1. Operations Research
2. Stochastic Process
3. Reliability Analysis
4. Decision Theory
5. Robust Methods
6. Survival Analysis
7. Bio-Statistics
8. Data Mining
9. Actuarial Statistics-I
10. Actuarial Statistics-II
11. Mathematical Models and Simulation
12. Categorical Data Analysis
13. Numerical Methods
14. Bayesian Inference
15. Statistical Quality Control,

or any other subject depending upon the expertise available.
DETAIL OF COURSES

The proposed outlines of the BS (4-YEAR) programme in Statistics are as follows:

STAT- 101: Introductory Statistics - I


Recommended Books

10.

STAT- 102: Introduction to Probability & Probability Distributions

Probability Concepts, Addition and Multiplication rules, bivariate frequency tables, joint and marginal probabilities, Conditional probability and independence, Bayes’ rule

Random Variables, Discrete Probability Distribution, Mean and Variance of a discrete random variable, Bernoulli trials, Properties, applications and fitting of Binomial, Poisson, Hypergeometric, Negative Binomial and Geometric distributions

15
Continuous Random Variable, probability density function and its properties, Normal Distribution and its properties, Standard Normal Curve

**Recommended Books:**

1. Cacoullos, T., Exercises in probability, Publisher: New York: Springer-Verlag, 2009

**STAT-202: Basic Statistical Inference**


Nature of Hypothesis Testing and Types of errors, Hypothesis Testing for Population Mean and variance

Inferences for Two Population Means, Large-sample inferences for Two Populations using Independent Samples, Inferences for the Mean of Two Normal Populations using Independent Samples (variances are assumed Equal/Not Equal). Inference for Two Populations Mean using Paired Samples

Inferences for Population Proportions, Confidence Intervals and hypothesis testing for Population Proportion, Inferences for Two Populations Proportions using Independent Samples, Estimation of sample size
Pre-Requisite- STAT-102

Recommended Books:


STAT- 203: Introduction to Regression Analysis and Experimental Design

Concepts of Regression and Correlation, Simple Linear regression, multiple linear regression, Inference regarding regression parameters, linear correlation: simple, partial and multiple correlation, Inference regarding correlation coefficient, Coefficient of determination

One-Way and Two-Way Analysis of Variance

Design of Experiments, Basic Principles of Design of Experiments, Description, Layout and Analysis of Completely Randomized Design, Randomized Complete Block Design and Latin Square Design, Multiple Comparisons (LSD and Duncan’s test)

Pre-Requisite: STAT-101

Recommended Books:

STAT- 201: Applied Statistics


Index numbers: construction and uses of index numbers, un-weighted index numbers (simple aggregative index, average of relative price index numbers), weighted index numbers (Lasplayers, Paaches and Fishers ideal index numbers), Consumer price index (CPI) and Sensitive Price Indicators

Time Series Analysis: Components of time series and their decomposition.

Vital Statistics: Meaning of vital statistics, registrations of Birth and death in Pakistan. Uses of vital statistics, short comings of vital statistics, rates and ratios (Sex ratio, child women ratio, birth and death ratio, population growth rate, classification of natal rates, death rates or mortality rates, crude death rate, specific death rate, infant mortality rate, case fatality rate, fertility rates, crude birth rate, specific birth rate, standardized death rate, reproduction rates, morbidity or sickness rates, marriage rates, divorce rates etc. general; fertility rate, total fertility rate.)

Pre-Requisite: STAT-101

Recommended Books:

STAT- 204: Statistical Packages

Introduction to Minitab, data manipulation in Minitab, graphical representation in Minitab, Qualitative and Quantitative data presentation and analyzing data in Minitab, Programming in Minitab

Introduction of SPSS, data manipulation in SPSS, simple arithmetic in SPSS, SPSS function related to probability distributions, SPSS modules, simple graphing in SPSS

Analysis using SPSS syntax programming

Note: Use of any other statistical package based upon the availability of the Software.

Pre-Requisite: STAT-202

Recommended Books:


STAT- 301: Probability Distributions-I

Distribution function, Probability mass function and probability density function. Joint and conditional distributions for two and more random variables, Marginal and conditional distributions, stochastic independence, Baye’s theorem, Mathematical expectation and its properties Conditional expectation, variance and moments, Probability generating function, Moment generating and characteristic functions and their properties, Relation between moments and cummulants, Probability distributions: Bernoulli, Binomial, Hypergeometric, Poisson, Negative binomial,
Geometric, Multinomial distribution. Normal approximation to binomial & Poisson distribution, Normal distribution with moments and cummulants

**Pre-Requisite: STAT-102**

**Recommended Books**


**STAT- 303: Sampling Techniques-I**

Advantages of sampling, requirements of a good sample, bias, sampling and non-sampling errors, Steps and problems involved in planning and conduct of census and their sources, sample surveys, Selection and estimation procedures. Description and properties of simple random sampling, Sampling for proportions and percentages, Estimation of
variances, standard errors and confidence limits, Sample size determination under different conditions, Description and properties of stratified random sampling, Formation of strata, Different methods of allocation of sample size, Systematic sampling, Ratio and regression estimates in simple and stratified random sampling

Pre-Requisite: STAT-201

Recommended Books:


STAT- 307: Regression Analysis

General linear model and its assumptions, Least squares estimators, Maximum Likelihood Estimator, tests of significance for regression model and regression parameters. Confidence intervals for regression parameters, Test of linearity of regression, Use of extraneous information
in linear regression model. Residual analysis, Detection and study of outliers, Polynomial regression, orthogonal polynomial, orthogonal regression analysis, Specification of models

Pre-Requisite: STAT-203

Recommended Books:


STAT- 305: Design and Analysis of Experiments-I

Principles of Design of Experiments, Analysis of variance and its assumptions, Cochran theorem, Fixed, random and mixed effect models, Completely Randomized, Randomized Complete Block, Latin square, Graeco-Latin square and cross-over designs, Missing observations, Relative efficiency of designs, Estimation of mean squares and their expectations, Multiple Comparisons tests

Analysis of covariance in CR, RCB designs, Estimation of missing values in analysis of covariance.

Effect of violation of assumptions and transformations

Pre-Requisite: STAT-203

Recommended Books:


STAT- 310: Non-Parametric Methods

Chi-Square Procedures: Chi-Square Goodness of fit Test, Chi-Square test of independence, Location estimates for single sample: The sign test, modified sign test, Wilcoxon signed rank test, confidence interval based on these tests. Runs test for randomness.

Distribution tests and rank transformation, Kolmogrov’s test, Lilliefor’s test and Shapiro-Wilks test for normality. Tests and estimation for two independent samples; the median test, Wilcoxon Mann – Whitney test. The Siegel – Tukey test, the squared rank test for variance, Smirnov test, Tests for paired samples, Kruskal – Wallis test, Friedman test, multiple comparison with the Friedman test, Cochran’s test for binary responses
Spearman’s rank correlation coefficient, Kendall’s rank correlation coefficient. Theil’s regression method

Pre-Requisite: STAT-202

Recommended Books:
3. Lehman, E.L. (1973), Nonparametric Statistical Methods, based on Ranks, Holden-Day San Francesco

STAT-302: Probability and Probability Distributions-II

Uniform, Lognormal, Exponential, Gamma, Laplace, Rayleigh, Weibell with moments and cummulants; Distributions of functions of random variables: Chi-square, t and F distributions, their derivations and properties. Central limit and Chebyshev’s theorems and other inequalities, Weak and Strong Laws of large numbers and their applications, Order statistics, Distributions of rth and sth order statistics, Bivariate Normal distribution.

Pre-Requisite: STAT-301

Recommended Books:

STAT- 304: Sampling Techniques-II

Cluster Sampling, Sub sampling, PPS-Sampling, Double Sampling, Multistage and Multiphase sampling, Thomson Hurwitz estimator, Comparison of different sample designs; non-response, their sources and bias, Randomized response, Critical study of National sample surveys conducted in Pakistan: Census of Agriculture Pakistan, Pakistan Demographic Survey (PDS) and National Population and Housing Census

Note: Practical’s of this course shall include visits of the students to various national statistical organizations and a report submitted to this effect.

Pre-Requisite: STAT-303

Recommended Books:


**STAT- 308: Econometrics**

Introduction to econometrics, Problems of autocorrelation, multicollinearity, heteroscedasticity and their solution; Ridge regression, Lagged variables, Dummy variables, Errors in Variables, Instrumental variables, System of simultaneous linear equations, Identification-Estimation method, indirect and two-stage least squares methods, restricted least squares. Test of identifying restrictions; Estimation with stochastic regressor, generalized least squares estimators.

**Pre-Requisite: STAT-307**

**Recommended Books:**


STAT- 306: Design and Analysis of Experiments-II

Factorial Experiments: 2\textsuperscript{nd}, 3\textsuperscript{rd} series and mixed level factorial experiments and their analyses.

Confounding in factorial experiments, Complete and partial confounding, Confounding in Fractional replications. Split-plot, split-split plot, strip plot and nested designs. Missing observations in Split plot design. Response surface designs.

Incomplete block designs: BIBD - Lattice designs, lattice square and Youden squares, PBIBD with recovery of intra-block information.

Pre-Requisite: STAT-305

Recommended Books:


STAT-311: Population Studies

Basic concepts of demography, Sources of demographic data: The population and housing census, Registration of vital events. Demographic surveys, Components of population growth, composition of population and vital events, Types and sources of errors, Data quality testing procedures, testing the accuracy of age and sex distribution, Fertility and mortality measures, Estimation from incomplete Data

Construction of complete and abridged life tables, Different types of life tables, Graphs of $l_x$, $q_x$ and $e_x$, Description and uses of life table columns.

Stationary population models, Population estimates and projections, Inter-censal estimates, Population projections through various methods. Theory of demographic transition, Stable and stationary population models, their applications and uses, Malthusian and post Malthusian theories of growth, Consequences of world population growth & population explosion; State of Population in Pakistan, Development of demographic profile in Pakistan, Recent demographic parameters. Current and future demographic activities in Pakistan

Recommended Books


9. Govt. of Pakistan (1998), National, Provincial and District census reports and other supplementary reports with respect to 1998 census; PCO, Islamabad.
10. Pakistan Demographic Survey (2007), Govt. of Pakistan.

STAT- 401: Statistical Inference-I


Pre-Requisite: STAT-302

Recommended Books:


STAT- 403: Multivariate Analysis

Introduction to Multivariate data analysis, Basics of matrix and vector algebra, Geometry of vectors and sample, Expectation of sample mean, covariance matrix, linear combination of variables. Generalized variance, Multivariate Normal Distribution: Multivariate Normal density and its properties, Sampling distribution of sample mean vector and covariance matrix including their large sample behavior. Assessing normality, transformation to make non-normal data to normal, Outliers, Hotelling’s $T^2$ and likelihood ratio tests, Inferences about mean vector(s), Confidence regions and simultaneous comparisons of component means, Multivariate Linear Regression.

Principal components analysis, Factor Analysis, Discrimination and Classification, Cluster Analysis

Recommended Books:


**STAT- 402: Statistical Inference-II**

Interval Estimation: Pivotal and other methods of finding confidence interval, confidence interval in large samples, shortest confidence interval, optimum confidence interval. Bayes’ Interval estimation


**Pre-Requisite:** STAT-401

**Recommended Books:**


STAT- 422: RESEARCH PROJECT / INTERNSHIP
ELECTIVE COURSES

STAT-405: Research Methodology


PRACTICAL: Survey of Literature on a Given Topic, Collection of References from Various Sources. Collection of Primary and Secondary Data, Arrangement of Primary and Secondary Data, Preparation of Scientific Report for Publication, if Possible

Pre-Requisite: STAT-304

Recommended Books:

STAT-406: Operations Research

History and definition of Operation Research, Introduction to linear programming, Formulation of LP model, Graphical solution of two variables, Standard Form, Simplex method, Duality theory; Sensitivity Analysis, Primal and dual form, Transportation Problem, Assignment problem. Network Analysis, PERT/CPM techniques, Queuing Models, Inventory models, Dynamic programming and simulation models

Recommended Books:

STAT- 407: Stochastic Processes


Recommended Books

STAT- 408: Reliability Theory

Basic concepts of reliability, Structural reliability, Life time distributions (Failure models): Hazard rate; Gamma, Weibull, Gumball, Log-Normal and Inverse Gaussian Distribution. Stochastic fatigue-rate models, Point and interval estimation, Fatigue-life model

Testing reliability hypothesis, Monte-Carlo simulations, distribution-free and Bayes’ methods in reliability, System reliability; series and parallel systems, Failure models, (k-out-of-m) New-better-than used models. Inferences for these models, Accelerated life testing

Recommended Books:

5. Lawless, J.F. “Statistical Model and Methods for Lifetime Data”.(2nd ed.)

STAT- 409: Time Series Analysis

Time series analysis: concepts, Stochastic Process, Stationary Time-Series, Exponential smoothing techniques, auto-correlation and auto-covariance, estimation of auto-correlation function (ACF) and Partial autocorrelation function (PACF) and standard errors, Periodogram, spectral density functions, comparison with ACF, Linear stationary models: Auto Regressive Moving Average (ARMA) and mixed models, Non-stationary models, general ARIMA notation and models, minimum mean square forecasting, ARIMA Seasonal Models
Recommended Books:


STAT-410: Decision Theory

The nature and concept of loss functions, parameters, decisions and sample spaces, Risk and average loss, Admissibility and the class of admissible decisions, Minimax principle and its application to simple decision problems, linear and quadratic losses and their uses in problems of estimation and testing hypotheses. Asymptotically minimax procedure, Prior distributions and conjugate priors, Bayes’ decision procedure. Admissibility of Bayes’ and minimax procedures. Game theory
Recommended Books:


STAT- 411: Robust Methods

Introduction to Robustness, Objective function, M-estimator of location, E-estimator, R-estimator and W-estimator, Redescending M-estimator's The Breakdown point of Robust estimator Influence function. M-estimator for scale, Outliers and influential observations, Outliers in Regression analysis

Recommended Books:


STAT- 412: Official Statistics

Official Statistics, Statistical system and international standards, set up of national statistical organization in Pakistan, its role in development of Statistics, working and publications.

Sources of official Statistics, National Database Registration Authority (NADRA) and its role, Economic Statistics producers, International classification and standards

Use of Statistics in administration and planning Concepts and evaluation of GDP, GNP, NNP, Balance of Trade and payments, Measurement of Income Distribution, Prices and price mechanisms. Deflation and Inflation of series, Industrial quantum index, National sample surveys and censuses conducted in Pakistan.
Note: Visit of major Statistical Organizations should be a part of the course. Alternatively, the department may invite experts from various statistical organizations.

Recommended Books:

6. Various Publications of PBS, State Bank of Pakistan, Ministry of Finance, etc.

STAT-413: Survival Analysis

Special features of Survival data: Patient time and study time, Survival function and hazard function, Time dependent and censored survival data. Nonparametric procedures: Estimation of Survival function, hazard function, median and percentiles of Survival times. Confidence interval and comparison of group; stratified and log-rank tests for trend, Modeling of Survival data; Hazard function modeling; its tests and confidence interval, The Weibull model for survival data, Exploratory data analysis and other models, Sample size requirement for survival study, Use of software for Survival analysis

Recommended Books:


**STAT- 414: Biostatistics**

Definition of Biostatistics, type of variables and observations in biological, health and medical sciences, Uniqueness in terms of behaviour of variables their domain, and units; Categorical, numerical and censored data. Populations, Target populations and sampled Population: Role of sampling in biostatistics, Size of samples of various types of studies, Proportions, rates and ratios; incidence, prevalence and odds. Distributional behaviour of biological variables (Binomial, Poisson and Normal), Role of transformation for analysis of biological variables, Probit and Logit transformations and their analysis, p values, its importance and role, Confidence Interval in simple and composite hypothesis testing

**Recommended Books:**


STAT-415: Data Mining

Introduction to databases including simple and relational databases, data warehouses, Review of classification methods from multivariate analysis; classification, decision trees: classification and regression trees. Clustering methods from both statistical and data mining viewpoints; vector quantization. Unsupervised learning from univariate and multivariate data; dimension reduction and feature selection. Supervised learning from moderate to high dimensional input spaces; artificial neural networks and extensions of regression models, regression trees. Association rules and prediction; applications to electronic commerce.

Recommended Books


STAT- 416: Actuarial Statistics-I

Introduction to actuarial Statistics, Utility theory, insurance and utility theory, models for individual claims and their sums, survival function, curate future lifetime, force of mortality

Life table and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables.

Multiple life functions, joint life and last survivor status, insurance and annuity benefits through multiple life functions, evaluation for special mortality laws

Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement, net single premiums and their numerical evaluations.

Distribution of aggregate claims, compound Poisson distribution and its applications

Recommended Books:


STAT-417: Actuarial Statistics-II

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding.

Life insurance: Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance, recursions, commutation functions.

Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities-immediate and apportionable annuities-due.

Net premiums: Continuous and discrete premiums, true monthly payment premiums, apportionable premiums, commutation functions, accumulation type benefits.

Payment premiums, apportionable premiums, commutation functions, accumulation type benefits.

Net premium reserves: Continuous and discrete net premium reserve, reserves on a semi-continuous basis, reserves based on true monthly premiums, reserves on an apportionable or discounted continuous basis, reserves at fractional durations, allocations of loss to policy years, recursive formulas and differential equations for reserves, commutation functions.

Some practical considerations: Premiums that include expenses-general expenses types of expenses, per policy expenses.

Claim amount distributions, approximating the individual model, stop-loss insurance.

Recommended Books:


**STAT- 418: Mathematical Modeling and Simulation**

Monte Carlo methods: Different methods of generating random numbers, generation of random variables, acceptance and rejection techniques from various distributions. Comparison of algorithms to generate random variables, generating random variables from failure rates, Generation from multinomial distribution / Monte Carlo integration, Gibbs sampling and other resampling techniques, Variance reduction techniques: importance sampling for integration, control variates and antithetic variables.

**Recommended Books:**


**STAT- 419: Categorical Data Analysis**

A brief history of categorical data analysis, Principles of likelihood-based inference, Sampling distributions for contingency tables, Measures of association for 2x2 tables, Testing independence in contingency tables, Exact inference for two-way tables, Inferences for three-way tables.

Introduction to generalized linear models, Logistic regression, Model building, Alternative link functions for binary outcome, Diagnostics, Exact
methods and conditional logistic regression, Methods for analyzing matched case-control data, Multinomial response models for nominal data, Multinomial response models for ordinal data.

Poisson regression model, Poisson regression for rates, Log linear models for contingency tables

**Recommended Books:**


**STAT-422: Bayesian Inference**

Conditional Probability, Prior information, Prior distributions, Methods of elicitation of prior distributions, Posterior distributions: The posterior means, medians (Bayes estimators under loss functions) and variances of univariate and bivariate posterior distributions, Non-informative priors: Methods of elicitation of non-informative priors, Bayesian Hypotheses Testing: Bayes factor; The highest density region; Posterior probability of the hypothesis.

**Recommended Books:**


STAT- 423: Statistical Quality Control

Concept of quality control and Quality assurance, Total Quality Management (TQM) Statistical Methods in Quality Improvement, Statistical Process Control (SPC), Statistical Quality Control (SQC), Shewhart control charts: philosophy, construction, advantages. CUSUM and moving average control charts: Average Run Length (ARL); Fast Initial Response (FIR). ARL and FIR for control charts

Process capability analysis: Process improvements using design of experiments.

Acceptance sampling for attributes and variables, Acceptance sampling plans: Single, double, and multiple sampling plans with their O.C. curves, Military Standard 501 Sampling Plans. Introduction to ISO- 9000 and ISO-14000 series

Pre-Requisite: STAT-301

Recommended Books:

Recommendations

The following recommendations were made by the committee to enhance the teaching and learning of Statistics:

1. Departments of Statistics in the universities should make efforts to interact with national and international statistical organizations such as PBS, industry and other users of statistics in the public and private sector.
2. Internship should be funded by the HEC and/or other funding agencies, and offered to the students.
3. All universities’ departments should develop and maintain an internship / career services department to facilitate the internship students of Statistics.
4. Most of the courses may be taught using statistical packages.
5. Since there is a shortage of highly qualified statisticians in Pakistan. Therefore, allocating extra quota for statistics students to pursue higher education is needed.
6. The committee strongly recommends the creation of “Department of Biostatistics” for teaching and research guidance at all medical colleges/universities and the posts of biostatisticians in all hospitals/other institutions.
7. Practicum conducted during the course work should be in the form of case studies. The data published by different organizations may be used in such case studies.
8. A course on Statistics may be added in curriculum of FSc (Pre-Medical & Pre-Eng.) to prepare students for their professional education.
9. The department of Statistics in each university may establish a statistics consultancy center to attract potential researchers. HEC should provide technical and financial support to these research cells.
10. Refresher courses for the faculty should be regularly arranged by the HEC.
11. HEC should support universities for the development of computer labs, departmental libraries, students and staff participation in seminars, workshops, and conferences.
12. The department websites should be updated on a regular basis so that research interests of the faculty may become public.

13. PGD (Post Graduate Diploma) / Short courses should be offered by the universities/department of Statistics to the non-statisticians.

14. Professional ethics should be an integral part of the training of students at both the undergraduate and graduate level.

15. Since 4 year BS Programme is equivalent to old M.Sc. Programme in Statistics, therefore, the relevant recruitment rules for the post of BPS-17 may be amended by the concerned departments (FPSC, Establishment Division) and B.S. (Four year Programme) may be added in the eligibility criteria for the posts.

16. The department of Statistics in each university should make concrete efforts for establishing university-industry linkages for MS level research.
Annexure “A”

COMPULSORY COURSES IN ENGLISH FOR BS (4 YEAR) IN BASIC & SOCIAL SCIENCES

English I  (Functional English)

Objectives:  Enhance language skills and develop critical thinking.

<table>
<thead>
<tr>
<th>Course</th>
<th>Contents</th>
</tr>
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<tbody>
<tr>
<td>Basics of Grammar</td>
<td></td>
</tr>
<tr>
<td>Parts of speech and use of articles</td>
<td></td>
</tr>
<tr>
<td>Sentence structure, active and passive voice</td>
<td></td>
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<tr>
<td>Practice in unified sentence</td>
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<tr>
<td>Analysis of phrase, clause and sentence structure</td>
<td></td>
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<tr>
<td>Transitive and intransitive verbs</td>
<td></td>
</tr>
<tr>
<td>Punctuation and spelling</td>
<td></td>
</tr>
</tbody>
</table>

Comprehension

Answers to questions on a given text

Discussion

General topics and every-day conversation (topics for discussion to be at the discretion of the teacher keeping in view the level of students)

Listening

To be improved by showing documentaries/films carefully selected by subject teachers

Translation skills

Urdu to English

Paragraph writing

Topics to be chosen at the discretion of the teacher

Presentation skills

Introduction

Note: Extensive reading is required for vocabulary building

Recommended Books:

1. Functional English
   a) Grammar

b) Writing

c) Reading/Comprehension

d) Speaking

English II (Communication Skills)

Objectives: Enable the students to meet their real life communication needs.

Course Contents

Paragraph writing
Practice in writing a good, unified and coherent paragraph

Essay writing
Introduction

CV and job application
Translation skills
Urdu to English

Study skills
Skimming and scanning, intensive and extensive, and speed reading, summary and précis writing and comprehension

Academic skills
Letter/memo writing, minutes of meetings, use of library and internet

Presentation skills
Personality development (emphasis on content, style and pronunciation)

Note: documentaries to be shown for discussion and review
Recommended Books:

**Communication Skills**

a) Grammar


b) Writing


c) Reading

1. Reading Advanced Brian Tomlinson and Rod Ellis, Oxford Supplementary Skills, Third Impression, 1991. ISBN 0 19 453403 0

2. Reading and Study Skills by John Langan


**English III (Technical Writing and Presentation Skills)**

**Objectives:** Enhance language skills and develop critical thinking

**Course Contents**

**Presentation skills**

**Essay writing**
Descriptive, narrative, discursive, argumentative

**Academic writing**
How to write a proposal for research paper/term paper
How to write a research paper/term paper (emphasis on style, content, language, form, clarity, consistency)

**Technical Report writing**

**Progress report writing**
Note: Extensive reading is required for vocabulary building

Recommended Books:

Technical Writing and Presentation Skills

a) Essay Writing and Academic Writing

b) Presentation Skills

c) Reading
The Mercury Reader, a Custom Publication, Compiled by Norther Illinois University. General Editors: Janice Neulib; Kathleen Shine Cain; Stephen Ruffus and Maurice Scharton. (A reader which will give students exposure to the best of twentieth century literature, without taxing the taste of engineering students)
Annexure “B”

Pakistan Studies (Compulsory)

Introduction/Objectives

- Develop vision of historical perspective, government, politics, contemporary Pakistan, ideological background of Pakistan.
- Study the process of governance, national development, issues arising in the modern age and posing challenges to Pakistan.

Course Outline

1. Historical Perspective
   b. Factors leading to Muslim separatism
   c. People and Land
      i. Indus Civilization
      ii. Muslim advent
      iii. Location and geo-physical features.

2. Government and Politics in Pakistan
   Political and constitutional phases:
   a. 1947-58
   b. 1958-71
   c. 1971-77
   d. 1977-88
   e. 1988-99
   f. 1999 onward

3. Contemporary Pakistan
   a. Economic institutions and issues
   b. Society and social structure
   c. Ethnicity
   d. Foreign policy of Pakistan and challenges
   e. Futuristic outlook of Pakistan
Recommended Books:

Annexure “C”

ISLAMIC STUDIES
(Compulsory)

Objectives:
This course is aimed at:
1. To provide Basic information about Islamic Studies
2. To enhance understanding of the students regarding Islamic Civilization
3. To improve Students skill to perform prayers and other worships
4. To enhance the skill of the students for understanding of issues related to faith and religious life.

Detail of Courses

Introduction to Quranic Studies
1) Basic Concepts of Quran
2) History of Quran
3) Uloom-ul-Quran

Study of Selected Text of Holy Quran
1) Verses of Surah Al-Baqra Related to Faith (Verse No 284-286)
2) Verses of Surah Al-Hujrat Related to Adab Al-Nabi (Verse No 1-18)
3) Verses of Surah Al-Mumanoon Related to Characteristics of faithful (Verse No 1-11)
4) Verses of Surah al-Furqan Related to Social Ethics (Verse No 63-77)
5) Verses of Surah Al-Inam Related to Ihkam (Verse No 152-154)

Study of Selected Text of Holy Quran
1) Verses of Surah Al-Ihzab Related to Adab al-Nabi (Verse No 6,21,40,56,57,58.)
2) Verses of Surah Al-Hashar (18,19,20) Related to thinking, Day of Judgment
3) Verses of Surah Al-Saf Related to Tafakar, Tadabar (Verse No 1,14)

Seerat of Holy Prophet (S.A.W) I
1) Life of Muhammad Bin Abdullah (Before Prophet Hood)
2) Life of Holy Prophet (S.A.W) in Makkah
3) Important Lessons Derived from the life of Holy Prophet in Makkah

Seerat of Holy Prophet (S.A.W) II
1) Life of Holy Prophet (S.A.W) in Madina
2) Important Events of Life Holy Prophet in Madina
3) Important Lessons Derived from the life of Holy Prophet in Madina

Introduction to Sunnah
1) Basic Concepts of Hadith
2) History of Hadith
3) Kinds of Hadith
4) Uloom –ul-Hadith
5) Sunnah & Hadith
6) Legal Position of Sunnah

Selected Study from Text of Hadith

Introduction to Islamic Law & Jurisprudence
1) Basic Concepts of Islamic Law & Jurisprudence
2) History & Importance of Islamic Law & Jurisprudence
3) Sources of Islamic Law & Jurisprudence
4) Nature of Differences in Islamic Law
5) Islam and Sectarianism

Islamic Culture & Civilization
1) Basic Concepts of Islamic Culture & Civilization
2) Historical Development of Islamic Culture & Civilization
3) Characteristics of Islamic Culture & Civilization
4) Islamic Culture & Civilization and Contemporary Issues

Islam & Science
1) Basic Concepts of Islam & Science
2) Contributions of Muslims in the Development of Science
3) Quran & Science

Islamic Economic System
1) Basic Concepts of Islamic Economic System
2) Means of Distribution of wealth in Islamic Economics
3) Islamic Concept of Riba
4) Islamic Ways of Trade & Commerce

Political System of Islam
1) Basic Concepts of Islamic Political System
2) Islamic Concept of Sovereignty  
3) Basic Institutions of Govt. in Islam

**Islamic History**

1) Period of Khlaft-E-Rashida  
2) Period of Ummayyads  
3) Period of Abbasids

**Social System of Islam**

1) Basic Concepts Of Social System Of Islam  
2) Elements Of Family  
3) Ethical Values Of Islam

**Recommended Books:**

1) Hameedullah Muhammad, *Emergence of Islam*, IRI, Islamabad  
2) Hameedullah Muhammad, *Muslim Conduct of State*  
3) Hameedullah Muhammad, *Introduction to Islam*  
4) Mulana Muhammad Yousaf Islahi,*  
9) Dr. Muhammad Zia-ul-Haq, *Introduction to Al Sharia Al Islamia* Allama Iqbal Open University, Islamabad (2001)
Annexure “D”

Note: One course will be selected from the following three courses of Mathematics.

COMPULSORY MATHEMATICS COURSES FOR BS (4 YEAR)
(FOR STUDENTS NOT MAJORING IN MATHEMATICS)

1. MATHEMATICS I (ALGEBRA)

Prerequisite(s): Mathematics at secondary level

Credit Hours: 3 + 0

Specific Objectives of the Course: To prepare the students, not majoring in mathematics, with the essential tools of algebra to apply the concepts and the techniques in their respective disciplines.

Course Outline:

Preliminaries: Real-number system, complex numbers, introduction to sets, set operations, functions, types of functions.

Matrices: Introduction to matrices, types, matrix inverse, determinants, system of linear equations, Cramer’s rule.

Quadratic Equations: Solution of quadratic equations, qualitative analysis of roots of a quadratic equations, equations reducible to quadratic equations, cube roots of unity, relation between roots and coefficients of quadratic equations.

Sequences and Series: Arithmetic progression, geometric progression, harmonic progression.

Binomial Theorem: Introduction to mathematical induction, binomial theorem with rational and irrational indices.

Trigonometry: Fundamentals of trigonometry, trigonometric identities.

Recommended Books:

Dolciani MP, Wooton W, Beckenback EF, Sharron S, Algebra 2 and Trigonometry, 1978, Houghton & Mifflin,

Boston (suggested text)

Kaufmann JE, College Algebra and Trigonometry, 1987, PWS-Kent Company, Boston

2. **MATHEMATICS II (CALCULUS)**

**Prerequisite(s):** Mathematics I (Algebra)

**Credit Hours:** 3 + 0

**Specific Objectives of the Course:** To prepare the students, not majoring in mathematics, with the essential tools of calculus to apply the concepts and the techniques in their respective disciplines.

**Course Outline:**

_Preliminaries:_ Real-number line, functions and their graphs, solution of equations involving absolute values, inequalities. _Limits and Continuity:_ Limit of a function, left-hand and right-hand limits, continuity, continuous functions.

_Derivatives and their Applications:_ Differentiable functions, differentiation of polynomial, rational and transcendental functions, derivatives. _Integration and Definite Integrals:_ Techniques of evaluating indefinite integrals, integration by substitution, integration by parts, change of variables in indefinite integrals.

**Recommended Books:**


Thomas GB, Finney AR, *Calculus* (11th edition), 2005, Addison-Wesley, Reading, Ma, USA

3. **MATHEMATICS III (GEOMETRY)**

**Prerequisite(s):** Mathematics II (Calculus)

**Credit Hours:** 3 + 0

**Specific Objectives of the Course:** To prepare the students, not majoring in mathematics, with the essential tools of geometry to apply the concepts and the techniques in their respective disciplines.

**Course Outline:**

_Geometry in Two Dimensions:_ Cartesian-coordinate mesh, slope of a line, equation of a line, parallel and perpendicular lines, various forms of equation of a line, intersection of two lines, angle between two lines, distance between two points, distance between a point and a line.
Circle: Equation of a circle, circles determined by various conditions, intersection of lines and circles, locus of a point in various conditions. Conic Sections: Parabola, ellipse, hyperbola, the general-second-degree equation

Recommended Books:
Kaufmann JE, College Algebra and Trigonometry, 1987, PWS-Kent Company, Boston

Annexure “E”

COURSE FOR NON-STATISTICS MAJOR IN SOCIAL SCIENCES

<table>
<thead>
<tr>
<th>Title of subject</th>
<th>Introduction of Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discipline</td>
<td>BS (Social Sciences)</td>
</tr>
<tr>
<td>Pre-requisites</td>
<td>SSC (Metric) level Mathematics</td>
</tr>
<tr>
<td>Credit Hours</td>
<td>03 + 00</td>
</tr>
<tr>
<td>Minimum Contact Hours</td>
<td>40</td>
</tr>
<tr>
<td>Assessment</td>
<td>written examination;</td>
</tr>
<tr>
<td>Effective</td>
<td>2008 and onward</td>
</tr>
</tbody>
</table>

Aims: To give the basic knowledge of Statistics and prepare the students not majoring in Statistics

Objectives: After completion of this course the student should be able to:

- Understand the use of the essential tools of basic Statistics;
- Apply the concepts and the techniques in their respective disciplines.

Unit 1. What is Statistics?
Definition of Statistics, Population, Sample, Descriptive and Inferential Statistics, Observations, Data, Discrete and continuous variables, Errors of measurement, Significant digits, Rounding of a
Unit 2. Presentation of Data

Introduction, basic principles of classification and Tabulation, Constructing of a frequency distribution, Relative and Cumulative frequency distribution, Diagrams, Graphs and their Construction, Bar charts, Pie chart, Histogram, Frequency polygon and Frequency curve, Cumulative Frequency Polygon or Ogive, Historigram, Ogive for Discrete Variable, Types of frequency curves, Exercises.

Unit 3. Measures of Central Tendency

Introduction, Different types of Averages, Quantiles, The Mode, Empirical Relation between Mean, Median and Mode, Relative Merits and Demerits of various Averages. Properties of Good Average, Box and Whisker Plot, Stem and Leaf Display, definition of outliers and their detection, Exercises.

Unit 4. Measures of Dispersion

Introduction, Absolute and relative measures, Range, Quartile Deviation, The Mean Deviation, The Variance and standard deviation, Change of origin and scale, Interpretation of the standard Deviation, Coefficient of variation, Properties of variance and standard Deviation, Standardized variables, Moments and Moments ratios, Exercises.

Unit 5. Probability and Probability Distributions

Discrete and continuous distributions: Binomial, Poisson and Normal Distribution. Exercises

Unit 6. Sampling and Sampling Distributions

Introduction, sample design and sampling frame, bias, sampling and non-sampling errors, sampling with and without replacement, probability and non-probability sampling, Sampling distributions for single mean and proportion, Difference of means and proportions, Exercises.

Unit 7. Hypothesis Testing

Introduction, Statistical problem, null and alternative hypothesis, Type-I and Type-II errors, level of significance, Test statistics, acceptance and rejection regions, general procedure for testing of hypothesis, Exercises.
Unit 8. Testing of Hypothesis- Single Population
Introduction, testing of hypothesis and confidence interval about the population mean and proportion for small and large samples, Exercises

Unit 9. Testing of Hypotheses-Two or more Populations
Introduction, Testing of hypothesis and confidence intervals about the difference of population means and proportions for small and large samples, Analysis of Variance and ANOVA Table, Exercises

Unit 10. Testing of Hypothesis-Independence of Attributes
Introduction, Contingency Tables, Testing of hypothesis about the Independence of attributes, Exercises

Unit 11. Regression and Correlation
Introduction, cause and effect relationships, examples, simple linear regression, estimation of parameters and their interpretation, Correlation, Coefficient of linear correlation, its estimation, and interpretation of $r$ and $R^2$. Multiple regression and interpretation of its parameters, Examples

Recommended Books
**MS STATISTICS** (2 Years programme)

MS Statistics will contain a total of 36 Credit Hours out of which 24(12+12) will comprise course work in the first two semesters (1st year of study) and final two semesters will be for thesis / research equivalent to 12 Credit Hours.

**Detail of Credit Hours is as follows:-**

<table>
<thead>
<tr>
<th>Semester</th>
<th>No. of Subjects</th>
<th>Credit Hours</th>
<th>Total Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>2nd</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>3rd + 4th</td>
<td>Thesis / Research Work</td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

**Total Credit Hours for MS Statistics** 36

The list of courses is as follows:

**Courses**

- Stat-701 Advanced Probability Theory (3 cr.hrs.)
- Stat-702 Linear Models (3 cr.hrs.)
- Stat-703 Advanced Statistical Inference (3 cr.hrs.)
- Stat-704 Advanced Regression Analysis (3 cr.hrs.)
- Stat-705 Advanced Design of Experiments (3 cr.hrs.)
- Stat-706 Advanced Multivariate Analysis (3 cr.hrs.)
- Stat-707 Econometrics for Count Data and Durations (3 cr.hrs.)
- Stat-708 Time Series Analysis and Forecasting (3 cr.hrs.)
- Stat-709 Advanced Categorical Data Analysis (3 cr.hrs.)
- Stat-710 Logical Reasoning and Research Methods (3 cr.hrs.)
- Stat-711 Survey Sampling (3 cr.hrs.)
- Stat-712 Measure Theory (3 cr.hrs.)
- Stat-713 Survival Data Analysis (3 cr.hrs.)
- Stat-714 Applied Stochastic Models (3 cr.hrs.)
- Stat-715 Spatial Data Analysis (3 cr.hrs.)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stat-716</td>
<td>Advanced Distribution Theory</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>Stat-717</td>
<td>Inference in Stochastic Processes</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>Stat-718</td>
<td>Advanced Bayesian Inference</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>Stat-719</td>
<td>Optimization Techniques</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>Stat-720</td>
<td>Statistical Ecology</td>
<td>(3 cr.hrs.)</td>
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<tr>
<td>Stat-721</td>
<td>Medical Statistics</td>
<td>(3 cr.hrs.)</td>
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<tr>
<td>Stat-722</td>
<td>Analysis of Clinical Trials</td>
<td>(3 cr.hrs.)</td>
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<tr>
<td>Stat-723</td>
<td>Financial Stochastic Models</td>
<td>(3 cr.hrs.)</td>
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<tr>
<td>Stat-724</td>
<td>Statistical Genetics</td>
<td>(3 cr.hrs.)</td>
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<tr>
<td>Stat-725</td>
<td>Generalized Linear Models</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>Stat-726</td>
<td>Repeated Measure Analysis</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>*Stat-727</td>
<td>Decision Trees</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>*Stat-728</td>
<td>Theory of Mixed Linear Models</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>*Stat-729</td>
<td>Advanced Operations Research</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>*Stat-730</td>
<td>Multilevel Modeling</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>*Stat-731</td>
<td>Environmental Statistics</td>
<td>(3 cr.hrs.)</td>
</tr>
<tr>
<td>*Stat-731</td>
<td>Advanced Statistical Methods in Quality Control</td>
<td>(3 cr.hrs.)</td>
</tr>
</tbody>
</table>

* These courses can be offered depending upon the availability of faculty. The syllabus will be formulated by the respective departments/universities.
Detail of courses

STAT- 701: Advanced Probability Theory  (3 Cr. Hours)

Algebra of sets, fields and sigma-fields, limits of sequences of subsets, sigma-field generated by a class of subsets, Borel fields, Probability, measure on a sigma-fields, probability space, continuity of a probability measure. Real and vector-valued random variables, distribution functions (d.f.) discrete r.v.s., r.v.s of the continuous type, decomposition of c.d.f, independence of two events and (n> 2) events, sequence of independent events, independent classes of events. Dynkin’s theorem, independence of r.v.s, Borel zero-one law, Expectation of a real r.v. and of a complex-valued r.v. Linear properties of expectations, characteristic functions, their simple properties, uniqueness theorem. Convergence of a sequence of r.v.s., convergence in distribution, convergence in probability, Kolmogorov strong law of large numbers (without proof), monotone convergence theorem and dominated convergence theorem, continuity theorem for characteristic functions. Lindeberg’s CLT and its particular cases, Cramer’s theorem on composition of convergence in distribution and convergence in probability.

Recommended Books:


STAT- 702: Linear Models  (3 Cr. Hours)

Recommended Books:


STAT- 703: Advanced Statistical Inference (3 Cr. Hours)

Objective of statistical analysis and theory, criteria for the choice of families of models, the likelihood, sufficient statistics, some general principals of statistics inference, significance tests: simple null hypothesis and simple alternative hypothesis, some example, discrete problems, composite alternatives, two-sided tests, Local power, Multidimensional alternatives, composite null hypothesis, similar Region, invariants tests, Distribution–free and randomization tests: permutation tests, Rank test, Randomization tests, distance tests, Interval estimation: Scalar parameter, scalar parameter with nuisance parameters, Vector parameter, estimation of future observations, Point estimation: General considerations on bias and variance, Cramer–Rao inequality, Achievement of minimum variance and remove of bias, estimates of minimum mean squared error, Robust estimation, Asymptotic theory: Introduction, maximum likelihood estimates, large sample parametric significance tests, Robust inference for location parameters.

Recommended Books:


STAT- 704: Advanced Regression Analysis (3 Cr. Hours)

Brief review of multiple regression by least-squares, Outliers: Analysis of residuals, Influence measure, identifying influential observations, Diagnostics Tests, Robust regression, Tests for normality, choosing a regression model using various computational techniques: All possible regressions, forward selection, backward elimination and stepwise regressions. Re-Sampling techniques: Jackknifing, Bootstrapping and Cross-Validation

Recommended Books:


STAT- 705: Advanced Design of Experiments (3Cr. Hours)

Incomplete Block Designs, Lattice square designs, generalized lattice designs, Alpha lattice designs, Youden Square, Change-Over Design, Cyclic Designs, and Response Surface Methodology, First and second order RS designs. Designs Robust to underlying Model, Outliers and Missing observations, Taguchi Methods., Optimal designs (An optimal, D optimal).

Recommended Books:

STAT-706: Advanced Multivariate Analysis (3 Cr. Hours)

Multivariate Normal Distribution, Wishart distribution and their properties, Hotelling’s $T^2$ Distribution, Methods of Estimation; Maximum Likelihood and least squares, Multivariate Hypothesis testing, Likelihood ratio test, One sample and multi-sample hypothesis. Principal Component Analysis, Factor Analysis, Discriminant Analysis. Canonical Correlation, Cluster analysis, Path analysis, Multivariate Analysis of variance (MANOVA)

Recommended Books:


STAT-707: Econometrics for Count Data and Durations (3 Cr. Hours)

Basic Count Regression Models: Count data basics, Specification and estimation of count regression models, Poisson MLE, PMLE and GLM. Negative Binomial MLE QGPMLE, Over Dispersion Tests, Ordered Models.
Generalized Count Regression Models, Mixture models for unobserved heterogeneity, Models based on waiting time distribution, Katz, Double Poisson and Generalized Poisson, Truncated and Censored Counts, Hurdle and Zero-inflated models


Recommended Books:

5. Van den Berg, G. J. (2001). Duration models: Specification, identification, and

STAT-708: Time Series Analysis and Forecasting (3 Cr. Hours)

Types of data, components of time series data, Stochastic processes, Stationary and non-stationary processes, Forms and tests of non-stationarity, Purely random processes, Random walk models, Lag operator, Difference equations and their solutions, Smoothing and decomposition methods, Univariate time series analysis (ARMA, ARIMA, Box-Jenkins approach, ARCH,GARCH etc.), Time series modeling and diagnostic checking, State space models and use of Kalman filter,
Multivariate time series analysis: Granger causality, Vector Autoregressive Models. Transfer function and intervention analysis, Time series forecasting, Co-integration analysis, Vector error correction model and Johansen approach.

**Recommended Books:**

STAT- 709: Advanced Categorical Data Analysis
(3 Cr. Hours)

Introduction to categorical data analysis, Principles of likelihood-based inference, Sampling distributions for contingency tables, Measures of association for 2x2 tables, Testing independence in contingency tables, Exact inference for two-way tables, Inferences for three-way tables.

Introduction to generalized linear models, Logistic regression, Model building, Alternative link functions for binary outcome, Diagnostics, Exact methods and conditional logistic regression, Methods for analyzing matched case-control data, Multinomial response models for nominal data, Multinomial response models for ordinal data. Poisson regression model, Poisson regression for rates, Log-linear models for contingency tables, Negative binomial models, Quasi-likelihood and Generalized Estimating Equations

Recommended Books:

**STAT- 710: Logical Reasoning and Research Methods**  
*(3 Cr. Hours)*

Propositions and arguments, recognizing arguments, validity and invalidity,  
fallacies, symbolizing arguments, truth functions, truth tables, proving  
validity and invalidity, science and scientific attitude, theory and fact,  
sources and properties of hypothesis, formulation of research problems  
and its significance, preparation of research design, components of  
research design, questionnaires and interviews, preparation of research  
report. Multidimensional scaling

**Recommended Books:**

   Co.
   Wadworth Publishing Co.

**STAT- 711: Survey Sampling**  
*(3 Cr. Hours)*

Non-Sampling Errors, Observational Errors, Incomplete Sampling, Non-  
response, Effects of Non-response, Response and Response Variance,  
Sources of Response Error, Detection, Control and Measurement of  
Response Error, Scaling Methods, Types of Scales, General Procedure in  
Attitude Scaling, Rating Scales, Likert Scale, Guttman Scale, Semantic  
Differential, A Survey of Super population Models. Randomization theory  
results for SRS Model for SRS, and model for ratio and Regression  
Estimation. Model for Stratified Sampling, Cluster Sampling, Models for  
equal Probability Sampling, Complex Surveys, Variance Estimations in  
Complex Surveys, Categorical Data Analysis in Complex Surveys,  
Regression Analysis for Complex Survey, Effects of Survey Design on  
Regression Analysis, Effects of Two-stage Sampling on OLS Methods,  
Comparison of Domain Means in Two-stage Sampling.

**Recommended Books:**

   New York.
   Publishing House, New Delhi.
   Surveys*. John Wiley and Sons.

**STAT-712: Measure Theory (3 Cr. Hours)**


**Recommended Books:**


**STAT-713: Survival Data Analysis (3 Cr. Hours)**


**Recommended Books:**


**STAT- 714: Applied Stochastic Models (3 Cr. Hours)**


**Recommended Books:**


STAT- 715: Spatial Data Analysis (3 Cr. Hours)
Introduction to spatial statistics and data handling, Eigen function analysis of aerial unit configuration, spatial auto-correlation and spectral analysis, models of spatial auto-correlation, higher order autoregressive models, relationship between autoregressive and spectral models Kriging.

Recommended Books

STAT- 716: Advance Distribution Theory (3 Cr. Hours)
Probability measures, expectations, conditioning, convergence of random sequences, law of large numbers, central limit theory, characteristic functions, discrete distributions, continuous distributions, systems of distributions: Pearson and Johnson, Chebyshev-Hermite polynomials, Gram-Charlier Series (Type-A), polynomial transformation to normality. Order statistics and their sampling

Recommended Books:
STAT- 717: Inference in Stochastic Processes
(3 Cr. Hours)

Inference in Markov chains, estimation of transition probabilities, testing for order of a Markov chain, estimation of functions of transition probabilities, parametric models and their goodness of fit

Markov sequences, estimation of parameters based on likelihood and conditional least squares, auto-regressive series, Statement of martingale, strong law of large numbers and Central Limit Theorem for martingales, CAN property of the MLE from a general sequence of dependent random variables, Fisher information, Applications to Markov chains and sequences.

Likelihood of Poisson and other Pure Jump Markov processes from first principles, CAN property of MLE’s, testing for a Poisson process, non-homogeneous processes, Analysis of parametric Pure Jump processes, Birth-Death-Immigration processes, testing goodness of fit of such models Diffusion processes and their likelihood, properties of estimators (without proof) Branching processes, Inconsistency of MLE/moment estimators, Properties of estimators on the non-extinction path, Asymptotic distribution theory.

Elements of semi-parametric and non-parametric analysis, Theory and applications of optimal estimating functions, estimation of transition and stationary density, intensity function of a counting process.

Recommended Books:

STAT- 718: Advanced Bayesian Inference (3 Cr. Hours)

Classical vs Bayesian Statistics, Statistical Inference, Bayes’ theorem; Likelihood, Prior distribution; Posterior distribution; Summaries of the univariate, bivariate & multivariate posterior distributions & applications. Posterior distributions using conjugate prior, Predictive distribution; Predictive inference, Methods of elicitation of non-information priors, Bayesian testing of hypothesis; Bayes factor for testing the sharp (point) hypothesis; The highest density region. Bayesian computation, e.g. Gibbs sampling, Bayesian Regression

Recommended Books:

STAT- 719: Optimization Techniques (3 Cr. Hours)

Convex sets, supporting and separating hyper-planes, program and basic feasible solution, simplex algorithm and simplex method, two phase method, graphical solution, Charnes’ M-technique.

Duality in linear programming, duality theorems, dual simplex method with justification, sensitivity and parametric linear programming

Transportation and assignment algorithms, balanced and unbalanced transportation problems, degeneracy, Hungarian method of assignment, transshipment problems.

Integer linear programming, Gomory cut method, branch and bound method, fractional cut method, Network flows, maximal flow in the network, labeling technique, connection between network flow and transportation, matrix solution.

Nonlinear programming, Integer Programming, Goal Programming, Quadratic programming, Kuhn – Tucker conditions, Algorithms (Wolfe’s Beale’s and Fletcher’s) for solving quadratic programming problem.

Recommended Books:

**STAT- 720: Statistical Ecology (3 Cr. Hours)**


**Recommended Books:**


**STAT- 721: Medical Statistics (3 Cr. Hours)**

Study designs in epidemiology, Measures of disease occurrence and association, variation and bias. Identifying non-causal association and confounding.
Defining and assessing heterogeneity of effects, interaction. Sensitivity and specificity of diagnostic test, Cohort Study designs, statistical power and sample size computations.
Log-linear models, 2xK and 2x2x2 contingency tables, Logistic model, Analysis of binary data. Cross-control study designs, matched case-control studies.

Survival data: Proportional hazards model, multivariate survival data, Causal Inference, Longitudinal data, communicating results of epidemiological studies, ethical issues in epidemiology

**Recommended Books:**

1. Agresti: Categorical Data Analysis.
5. Diggle, Liang and Zeger: Analysis of longitudinal data
8. Piantadosi: Clinical trials
10. Selvin: Statistical analysis of epidemiological data.
11. Zhou, Obuchowski and McClish: Statistical Methods in Diagnostic Medicine

**STAT- 722: Analysis of Clinical Trials**  
(3 Cr. Hours)

Introduction to clinical trials: the need and ethics of clinical trials, bias and random error in clinical studies, conduct of clinical trials, overview of Phase I-IV trials, multi-center trials. Data management: data definitions, case report forms, database design, data collection systems for good clinical practice.

Design of clinical trials: parallel vs. cross-over designs, cross-sectional vs. longitudinal designs, review of factorial designs, objectives and endpoints of clinical trials, design of Phase I trials, design of single-stage and multi-stage Phase II trials, design and monitoring of Phase III trials with sequential stopping, design of bio-equivalence trials.

Reporting and analysis: analysis of categorical outcomes from phase I – III trials, analysis of survival data from clinical trials.

Recommended Books:


STAT-723: Financial Stochastic Models (3 Cr. Hours)

Derivatives: forward and future contracts. Markets, prices, arbitrage and hedging, Options markets, properties of stock option prices.

Recommended Books

2. John Hull L: Options, futures and other derivatives(Prentice Hall)

STAT-724: Statistical Genetics (3 Cr. Hours)

Basic concepts in genetics, Bioinformatics, Population Genetics, Evolutionary Genetics, Genetic Epidemiology, Plant and Animal Genetics sample designs, gene frequency estimation, Hardy-Weinberg equilibrium, linkage disequilibrium, association and transmission disequilibrium test studies, linkage and pedigree analysis, segregation analysis, polygenic models, DNA sequence analysis, Hypothesis testing and categorical data , Chi-square test, Transmission Disequilibrium test
Recommended Books:

1. A Statistical Approach to Genetic Epidemiology by Andreas Ziegler and Inke R. König (Jun 22, 2010).

STAT-725: Generalized Linear Models (3 Cr. Hours)


Recommended Books


**STAT- 726: Repeated Measure Analysis  (3 Cr. Hours)**

Introduction of repeated measure designs, models and assumptions, variance–covariance structure, box’s correction, Huynh-Feldt (HF) condition, circularity assumption, necessary and sufficient conditions for circularity, mauchley sphere city test, trend analysis, test of trend analysis, models with interaction, measures of association and power in univariate repeated measure design, application of repeated measure in basic design and analysis of co-variance, multi factor experiments in repeated measure designs, two factors experiment with one factor repeated measure, three factor experiments with repeated measure, controlling sequence effect, unequal group size, measures of association and statistical power in multifactor repeated measure designs.

**Recommended Books:**

STAT- 727: Decision Trees (3 Cr. Hours)
Meaning of classification, classifier and an overview of classification techniques, Difference between supervised and un-supervised learning/classifiers, Decision trees and their generation procedures (tree growing process), role of evaluation functions to split parent node into two sub-nodes, Various node splitting evaluation functions (impurity-based and non-impurity-based) including Gini index, Twoing rule and Entropy function. Properties of impurity-based evaluation functions, Selection criterion to split a node, Estimation of error rates and right sized classification trees. Construction of classification trees; evaluating the performance of a classifier: Holdout Method, Random Sub-Sampling, Cross-Validation and Bootstrap Samples

Recommended Books:

Stat – 728: Theory of Mixed Linear Models (3 Cr. Hours)
Linear models, factors and levels, fixed effects and random effects models, linear mixed models (LMMs), estimation of fixed effects in LMMs, estimation of variance components: Maximum Likelihood Estimation (MLE), Restricted Maximum Likelihood (REML) Estimation Method and Minimum Norm Quadratic Method of Estimation (MINQUE); prediction of random effects, Best Linear Unbiased Prediction (BLUP) method, testing of hypotheses in LMMs, likelihood ratio tests for random effects, likelihood ratio tests for residual variance, F-tests and likelihood ratio tests for fixed effects, analysis of unbalanced and missing data, mixed model diagnostics, residual diagnostics, conditional residuals, conditional
studentized residuals, influence measures for diagnostics, overall and fixed-effects influence diagnostics.

**Recommended Books:**


**STAT- 729: Advanced Operations Research (3 Cr. Hours)**


Reliability Theory: Introduction, failure phenomenon: Exogenous and Endogenous – Type Failure, Statistical Characteristic of system subject to failure, stochastic process underlying the failure phenomenon, Determination of the failure characteristic of a system given the failure characteristic of its component-serial system, methods for improving the Reliability of a system.

Queuing Theory: Introduction and Historical Background, characteristic of Queuing System, characteristic of Queuing Problems, the M/M/1 Queuing, the M/M/r queueing system, the modified M/G/1 Queuing System the M/G/r Queuing System, control of single server Queuing system.

Inventory theory for single commodity single installation system: Introduction, deterministic Inventory Models, Stochastic Inventory Models.
Recommended Books:


Stat – 730: Multilevel Modeling (3 Cr. Hours)

Introduction to multilevel modeling, Scope of multilevel models in various fields,

comparison of multilevel models with traditional regression models, two level random effect multilevel models and interpretation of parameters, estimation of parameters in multilevel models, concept of intra-class correlation in multilevel (ML) models, fitting multilevel models and criteria for the goodness of the ML models, Sample size estimation for ML models, effect of sample size on the properties of multilevel model estimates, application of multilevel models (using statistical packages such as MLwin or HLM).

Recommended Books:


STAT- 731: Environmental Statistics (3 Cr. Hours)

The Role of Statistics in Environmental Science, Environmental Sampling, Models for Data, Outliers, Environmental Monitoring, Impact Assessment, Inaccessible and Sensitive data, Environmental Standards, Time Series Analysis, Spatial Data Analysis, Censored Data, Monte Carlo Risk Assessment

Recommended Books:

STAT- 732: Advanced Statistical Methods in Quality Control (3 Cr. Hours)


Recommended Books:

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