

CURRICULUM
OF
STATISTICS
BS/MS

(Revised 2013)



HIGHER EDUCATION COMMISSION
ISLAMABAD

CURRICULUM DIVISION, HEC

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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).

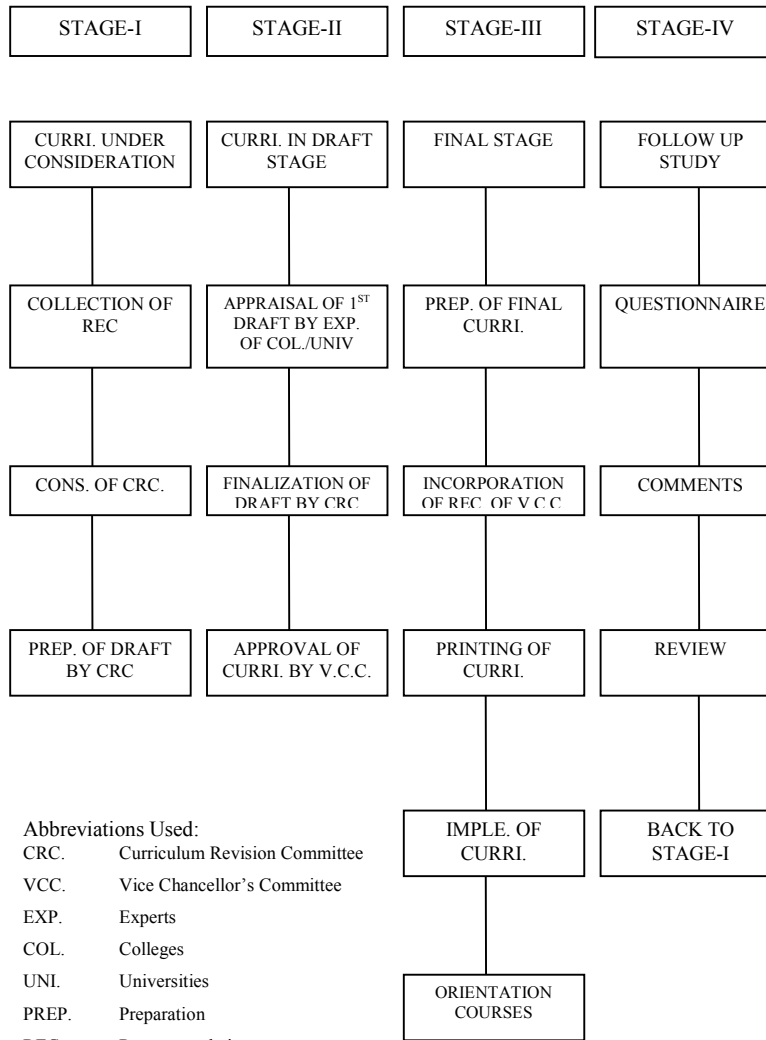
In compliance with the above provisions, the Curriculum Division of HEC undertakes the revision of curricula after every three years through respective National Curriculum Revision Committees (NCRCs) which consist of eminent professors and researchers of relevant fields from public and private sector 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



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 Department of Statistics University of Peshawar, Peshawar.	Convener
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.	

11.	Dr. Yousaf Hayat, Associate Professor Department of Statistics Mathematics Statistics & Computer Sciences, KPK Agricultural University Peshawar.
12.	Prof. Dr. Muhammad Inayat Khan Department of Mathematics and Statistics University of Agriculture, Faisalabad.
13.	Mr. Habib Ullah Khan Census Commissioner Pakistan Bureau of statistics HQ, Islamabad.
14.	Dr. Asifa Kamal, Assistant Professor Department of Statistics Lahore College for Women University, Lahore.
15.	Dr. Faisal Maqbool Zahid Assistant Professor Department of Statistics Government College University Faisalabad. Secretary

2. 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.

3. 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

Compulsory Requirements (the student has no choice)		General Courses to be chosen from other departments		Discipline Specific Foundation Courses	
9 courses		7-8 courses		9-10 courses	
25 Credit hours		21-24 Cr. Hours		30-33 Credit hours	
Subject	Cr Hr	Subject	Cr Hr	Subject	Cr Hr
1. English I	3	1. Introduction to Psychology	3	Introductory Statistics	3
2. English II	3	2. Introduction to Logic	3	Introduction to Probability & Probability Distributions	3
3. English III	3	3. Fundamentals of Economics	3	Basic Statistical Inference	3
4. Communication Skill	3	4. International Relations	3	Linear Algebra	3
5. Pakistan Studies	2	5. Basics of Sociology	3	Introduction to Regression Analysis & Experimental Design	3
6. Islamic Studies / Ethics	2	6. Introduction to Environmental Sciences	3	Applied Statistics	3
7. Calculus-I	3	7. Principles of Management	3	Probability Distribution-1	3
8. Calculus-II	3	8. Business Administration 9. (Entrepreneurship)	3	Sampling Techniques-I	3
9. Introduction to Computer	3	OR * from the list of general courses given in Annexure on Page 5		Statistical Packages	3
TOTAL	25		21		27

Major courses including research project/internship		Elective Courses within the major	
11-13 courses		4 courses	
36-42 Credit hours		12 Credit Hours	
Subject	Cr Hr	Subject	Cr Hr
1. Regression Analysis	4	1. Operations Research	3
2. Design & Analysis of Experiment-I	4	2. Stochastic Process	3
3. Probability and Probability Distribution-II	3	3. Reliability Analysis	3
4. Sampling Techniques-II	4	4. Time Series Analysis	3
5. Econometrics	4	5. Research Methodology	3
6. Design & Analysis of Experiment-II	4	6. Non-Parametric Methods	3
7. Statistical Inference-1	3	OR ** from the list of elective courses.	
8. Multivariate Analysis-I	3		
9. Multivariate Analysis-II	4		
10. Population Studies	3		
11. Statistical Inference-II	4		
12. Official Statistics	3		
13. Research Project / Internship	3		
TOTAL	46		12

MODEL SCHEME OF STUDIES FOR BS (4-YEAR) IN STATISTICS

Semester / Year	Name of Subject	Credits
First	Introductory Statistics	3
	Pakistan Studies	2
	English-I (Functional English)	3
	Calculus-I	3
	General-I	3
	General-II	3
		17
Second	Introduction to Probability Distributions	3
	Islamic Studies/Ethics	2
	English-II	3
	Calculus-II	3
	General-III	3
	General-IV	3
		17
Third	Basic Statistical Inference	3
	English-III	3
	Introduction to Computer	3
	General-V	3
	General-VI	3
		15
Fourth	Applied Statistics	3
	Introduction to Regression Analysis & Experimental Design	3
	Communication Skills	3
	Linear Algebra	3
	General-VII	3
		15
Fifth	Probability Distribution-1	3
	Sampling Technique-I	4
	Design & Analysis of Experiment-I	4
	Regression Analysis	4
	Statistical Packages	3
		18
Sixth	Probability Distribution-II	3
	Sampling Techniques-II	4
	Design & Analysis of Experiment-II	4

	Econometrics	4
	Official Statistics	3
		18
Seventh	Statistical Inference-1	3
	Applied Multivariate Analysis	4
	Time Series Analysis	3
	Elective I	3
	Elective-II	3
		16
Eight	Statistical Inference-II	3
	Population Studies	4
	Research Project / Internship	3
	Elective-III	3
	Elective-IV	3
		16
	Total	132

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

The nature and scope of the Statistics, Variables and their types, Data and its sources, Scales of measurements, Tabulation and classification of data, Graphs and Charts: Stem-and leaf diagram, Box and Whisker plots and their interpretation. Measures of Central Tendency, Quantiles, Measures of Dispersion: Their properties, usage, limitations and comparison. Moments, Measures of Skewness and Kurtosis and Distribution shapes. Rates and ratios, Standardized scores

Recommended Books

1. A basic course in statistics / G.M. Clarke, D. Cooke. Edition: 5th ed. Publisher: London : John Wiley, 2004
2. Chaudhry, S.M.and Kamal, S. (2008), "*Introduction to Statistical Theory*" Parts I & II, 8th ed, Ilmi Kitab Khana, Lahore, Pakistan.
3. Mann, P. S. (2010) Introductory Statistics. Wiley.
4. Mcclave, J.T.,Benson, P.G. and Snitch, T. (2005) "*Statistics for Business & Economics*" 9th ed. Prentice Hall, New Jersey.
5. Schaum's outline of theory and problems of beginning statistics / Larry J. Stephens. Edition: 2nd ed. Publisher: New York : McGraw-Hill, 2006
6. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "*Probability and Statistics*", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
7. Sullivan, M., Fundamentals of statistics, III. Edition: 3rd ed. Publisher: Boston: Prentice Hall, 2011.
8. Walpole, R.E., Myers, R.H and Myers, S.L. (1998), "*Probability and Statistics for Engineers and Scientist*" 6th edition, Prentice Hall, NY.
9. Weiss, N.A.(1997), "*Introductory Statistics*" 4th ed. Addison-Wesley Pub. Company, Inc.
- 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

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
2. Chaudhry, S.M. and Kamal, S. (2008), "*Introduction to Statistical Theory*" Parts I & II, 8th ed, Ilmi Kitab Khana, Lahore, Pakistan.
3. Mann, P. S. (2010) *Introductory Statistics*. Wiley.
4. Clark, G.M. and Cooke, D. (1998), "*A Basic Course in Statistics*" 4th ed, Arnold, London.
5. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "*Statistics for Business & Economics*" 9th Edition. Prentice Hall, New Jersey.
6. Santos.D., *Probability: an introduction*, Publisher: Sudbury, Mass.: Jones and Bartlett Publishers, c2011.
7. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "*Probability and Statistics*", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
8. Walpole, R.E., Myers, R.H and Myers, S.L. (2007), "*Probability and Statistics for Engineers and Scientist*" 7th edition, Prentice Hall, NY.
9. Weiss, N.A. (1997), "*Introductory Statistics*" 4th ed. Addison-Wesley Pub. Company, Inc.

STAT- 202: Basic Statistical Inference

Sampling distribution: concepts and properties, Central limit theorem. Estimation: Point Estimation. Desirable Properties of a Good Estimator, Interval Estimation, Interval Estimation of population mean. Large and small sample confidence intervals for Population Mean

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:

1. Chaudhry, S.M. and Kamal, S. (2008), "*Introduction to Statistical Theory*" Part I, II, 8th ed, Ilmi Kitab Khana, Lahore, Pakistan.
2. Clark, G.M. and Cooke, D. (1998), "*A Basic Course in Statistics*" 4th ed, Arnold, London.
3. Mclave, J.T., Benson P.G. and Snitch, T. (2005) "*Statistics for Business & Economics*" 9th Prentice Hall New Jersey.
4. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "*Probability and Statistics*", 2nd ed. Schaums Outlines Series. McGraw-Hill. NY.
5. Walpole, R.E., Myers, R.H. and Myers, S.L. (2007), "*Probability and Statistics for Engineers and Scientist*" 7th edition, Prentice Hall, NY.
6. Weiss, N.A. (1997), "*Introductory Statistics*" 4th ed. Addison-Wesley Pub. Company, Inc.

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:

1. Chaudhry, S.M., and Kamal, S., (2009), "*Introduction to Statistical Theory*" Part I, II, 8th ed, Ilmi Kitab Khana, Lahore, Pakistan.
2. Clark, G. M. and Kempston, R. E. (1997), "*Introduction to the Design & Analysis of Experiment*" Arnold London.
3. Walpole, P.E., Myers R.H., Myers S.L. (2007), "*Probability and Statistics for Engineers and Scientists*", 7th ed. Prentice Hall.
4. Weiss, N.A, (1997), "*Introductory Statistics*" 4th ed. Addison-Wesley Pub. Company, Inc.

STAT- 201: Applied Statistics

Sampling: Sample versus population, Sampling, advantages of sampling, statistic and parameter. Probability sampling techniques: Simple Random sampling, Stratified random sampling, Systematic random sampling, Cluster Sampling. Non-probability sampling techniques: Quota sampling, purposive sampling, Snowball sampling. Census and survey problem, framing of questionnaire, Sampling and Non-Sampling Errors

Index numbers: construction and uses of index numbers, un-weighted index numbers (simple aggregative index, average of relative price index numbers), weighted index numbers (Laspeyres, Paasche and Fisher's 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, shortcomings 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:

1. Chaudhry, S.M. and S. Kamal, (2009), "*Introduction to Statistical Theory*" Part I, II, 8th Ed, Ilmi Kitab Khana, Lahore, Pakistan.
2. Clark, G.M. and Cooke, D. (1998), "*A Basic Course in Statistics*" 4th ed, Arnold, London.
3. Cochran, W.G. (1977) "*Sampling Techniques*". 3rd Ed.
4. McClave, J.T. Benson, P.G. and Snitch, T. (2005) "*Statistics for Business & Economics*" 9th Edition, Prentice Hall, New Jersey.
5. Pollard, A.H. Yousuf, F. and Pollard G.M. (1982), "*Demographic Techniques*", Pergamon Press, Sydney.
6. Walpole, P.E. Myers, R.H., Myers S.L. (1998), "*Probability and Statistics for Engineers and Scientists*", Prentice Hall.

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:

1. Colin D. Gray and Paul R. Kinnear, IBM SPSS statistics 19 made simple. Publisher: New York: Psychology Press, 2012.
2. Kerr A. W., Hall, H. K., and Kozub, S. A. (2002) Doing Statistics with SPSS. Sage Publications.
3. SPSS (2010) SPSS Statistics 19 Core System User's Guide.
4. Marques de Sá, Joaquim P.(2003) Applied **Statistics using SPSS, STATISTICA and MATLAB**
5. Norusis, Marija (2006) SPSS 14.0 Guide to Data Analysis, Prentice Hall, New Jersey.
6. Ryan, Barbara F.; Joiner, Brian L. and Cryer, Jonathan D.(2005) MINITAB Handbook, 5th Edition, Duxbury Press, California.
7. Susan A. Nolan and Thomas E. Heinzen. Study Guide & SPSS Manual to accompany statistics for the behavioral sciences Edition: 2nd ed. Publisher: New York : Worth Publishers, 2012

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

1. Fridett, B. & Gray, L. (1997). "A Modern Approach to Probability Theory" Birkhallser, Boston.
2. Freund, J. E. (1997). "Mathematical Statistics", Prentice Hall, New Jersey 6th edition.
3. Haq, M. (1984). *Foundation of Probability and Statistics*, Tahir sons, Urdu Bazar, Karachi.
4. Hirai, A.S. (2002), "A Course in Mathematical Statistics", Ilmi Kutab Khana, Lahore.
5. Hogg, R.M. and Craig, A.T. (1995), "Introduction to Mathematical Statistics". Prentice Hall, Engle wood Cliffs, New Jersey.
6. Khan, M. K., (1996). "Probability with Applications", Maktiba Ilmi, Lahore.
7. Mood, A.M, Graybill, F.A. and Boes, D.C. (1997), "Introduction to the Theory of Statistics", McGraw Hill, New York.
10. Norman L. Johnson , Samuel Kotz , N. Balakrishnan (1994). Continuous Univariate Distributions, Vol. 1 (Wiley Series in Probability and Statistics), Wiley-Interscience: New York.
11. Samuel Kotz , N. Balakrishnan, Norman L. Johnson (2000). Continuous Multivariate Distributions, Volume 1, Models and Applications, 2nd Edition, Wiley-Interscience: New York.
12. Sheldon Ross (2009). First Course in Probability, (8th Edition), Pearson
Stirzaker, D. (1999). "Probability and Random Variables". Cambridge University Press, Cambridge.
13. Stuart, A. and Ord, J .K. *Kendall's'* (1998), "Advanced Theory of Statistics", Vol. I, Charles Griffin, London.

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:

1. Brewer, K. R. & Hanif, M. (1983). Sampling with Unequal Probabilities, Lecture Notes in Statistics Series, No. 15, Springer Verlag.
2. Bethelam, J. (2009) Applied Survey Methods: A Statistical Perspective. Willey.
3. Chambers, R. L., and Skimmer, C. J. (2003) Analysis of Survey Data. Wiley.
4. Chaudhary, A., and Stemger, H. (2005), Survey sampling theory and methods. Chapman & Hall.
5. Cochran, W.G. (1977), "*Sampling Techniques*", 3rd ed, John Wiley and Sons, New York.
6. Ferguson, T.S. (1996), "*A Course in large Sample theory*, Chapman & Hall, London.
7. Kish, L. (1992). "*Survey Sampling*", John Wiley, New York.
8. Paduri S. R. S. Rao (2000) Sampling Methodologies with Applications, Chapman & Hall
9. Raj, D. (1971) "*Design of Sample Survey*". McGraw Hill, New York.
10. Raj, D. & Chandhok, P. (1998), "*Sample Survey Theory*". Narosa Publishing House, New Delhi.
11. Singh, R. and Singh N, (1996), "*Elements of Survey Sampling*", Kulwar Academic Publisher, Dodrecht.
12. Sukhatme, P.V, Sukhatme, B., Sukhatme, S., and Asok, A. (1985), "*Sampling Theory of Survey with Application*". Iowa State University Press

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:

1. Baltagi, B. H. (1999). *"Econometrics"*, 2nd Edition, Springer Varlog.
2. Johnston, J. and Di. Nardo, J., (1997). *"Econometric Method"*, 4th Edition, McGraw-Hill, New York.
3. Maddala, G.S. (1977). *"Econometrics"*, McGraw Hill. New York.
4. Searle, S. R. (1971), *"Linear Models"*, John Wiley, New York.
5. Yan, X. and Zu, X. G. (2009) *Linear Regression Analysis: Theory & Computing*. World Scientific Publications.
6. Wonnacott, T.H. and Wonnacott R.J. (1998). *"Econometrics"*, John Wiley, New -York.

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:

1. Boniface, D.R. (1995). *"Experiment Design & Statistical Methods"*, Chapman & Hall.
2. Cochran, W.G. and Cox, G.M. (1992). *"Experimental Design"*, John Wiley, New York.

3. Clarke, G.M. (1994). "*Statistics & Experimental Design*". Edward Arnold.
4. Clarke, G.M., and Kempton, R.E. (1997), "*Introduction to the Design & Analysis of Experiments*", Edward Arnold.
5. Das, M.N. and Geri, N.C. (1986). "*Design and Analysis of Experiments*", John Wiley, New York.
6. Gomez, K.A., and Gomez, A.A. (1984). "*Statistical Procedures for Agricultural Research*", 2nd Edition, John Wiley, New York.
7. Harold, R. L (1992). "*Analysis of Variance in Experimental Design*". Springer Verlage
8. Hicks, C.R. (1982). "*Fundamental Concepts in Design and Analysis of Experiments*" Saunders
9. Hunter, B. and Hunter, W. G. (2005) *Statistics for Experimenters: Design, Innovation and Discovery*. Wiley.
10. Maxwell, S.E. and Delaney, H.D. (1990). "*Designing Experiments and Analysis of Data*". *A model comparison perspective*. Belmont and Wadson.
11. Mead, R. (1988). "*The Design of Experiments*". Cambridge University Press, Cambridge.
12. Montgomery, D. C., *Design and analysis of experiments*, Edition: 7th ed. Publisher: New Jersey : John Wiley, 2009
13. Myers, R.H. and Montgomery, D.C. (1995). "*Response Surface Methodology; Process & Product Optimization Using Design*", John Wiley.
14. Steel, Robert, G. D., Terrie James H., and Dickey David A. (1997). "*Principles and Procedures of Statistics: A Biometrical Approach*" 3rd Edition, McGraw-Hill, New York.

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, Kolmogorov's test, Lilliefors' 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:

1. Conover, W.J. (1999), *Practical Nonparametric Statistics*, 3rd Edition, John Wiley and Sons, New York
2. Gibbons, J.D. and Chakraborti, S. (1992), *Nonparametric Statistical Inference*, Marcel Decker, New York.
3. Lehman, E.L. (1973), *Nonparametric Statistical Methods, based on Ranks*, Holden-Day San Francisco
4. Maritz, J.S. (1995). *Distribution-Free Statistical Methods*, Chapman & Hall London
5. Sprint, P. (2007). *Applied Nonparametric Statistical Methods, 4th edition*, Chapman & Hall London

STAT- 302: Probability and Probability Distributions-II

Uniform, Lognormal, Exponential, Gamma, Laplace, Rayleigh, Weibull 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:

1. Dekking, F. M., Kraaikamp, C., and Lopuhaae, H. P., and Meester, L. E. (2005) *A Modern Introduction to Probability and Statistics*. Springer.
2. Fridett, B. & Gray, L. (1997). "*A Modern Approach to Probability Theory*" Birkhallser, Boston.
3. Freund, J. E. (1997). "*Mathematical Statistics*", Prentice Hall, New Jersey.
4. Haq, M. (1984). "*Foundation of Probability and Statistics*", Tahir sons, Urdu Bazar, Karachi.
5. Hirai, A.S. (1998), "*A Course in Mathematical Statistics*", Ilmi Kutab Khana, Lahore.
6. Hogg, R.M. and Craig, A.T. (1995), "*Introduction to Mathematical Statistics*". Prentice Hall, Engle wood Cliffs, New Jersey.

7. Khan, M. K., (1996). "*Probability with Applications*", Maktiba Ilmi, Lahore.
8. Mood, A.M, Graybill, F.A. and Boss, D.C. (1997), "*Introduction to the Theory of Statistics*", McGraw-Hill, New York.
9. Stirzaker, D. (1999). "*Probability and Random Variables*". Cambridge University Press, Cambridge.
10. Stuart, A. and Ord, J .K. *Kendall's* (1998), "*Advanced Theory of Statistics*", Vol. I, Charles Griffin, London.

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:

1. Brewer, K. R. & Hanif, M. (1983). Sampling with Unequal Probabilities. Lecture Notes in Statistics Series, No. 15, Springer Verlag.
2. Bethelam, J. (2009) Applied Survey Methods: A Statistical Perspective. Wiley.
3. Chambers, R. L., and Skimmer, C. J. (2003) Analysis of Survey Data. Wiley.
4. Chaudhary, A., and Stemger, H. (2005), Survey sampling theory and methods. Chapman & Hall.
5. Cochran, W.G. (1977), "*Sampling Techniques*", John Wiley and Sons, 3rd ed, New York.
6. Des Raj, (1971), *Design of Sample Survey*. McGraw-Hill, New York.
7. Des Raj & Chandhok, P. (1998), "*Sample Survey Theory*". Narosa Publishing House, New Delhi.

8. Ferguson, T.S. (1996), "*A Course in Large Sample Theory*", Chapman & Hall, London.
9. Hansen, M. H., Hurwitz, W. N. & Madow, W.G. (1952).
10. Kish, L. (1992), "*Survey Sampling*", John Wiley, New York.
11. Singh, R. and Singh N, (1996), "*Elements of Survey Sampling*", Kulwar, Dodrecht.
12. Sukhatme, P.V, Sukhatme, B., Sukhatme, S., and Asok, A. (1985), "*Sampling Theory of Survey with Application*". Iowa State University Press.
13. Sukhatme, P.V, Sukhatme, B., Sukhatme, S., and Asok, A. (1985), "*Sampling Theory of Survey with Application*". Iowa State University Press.
14. Various publications of Pakistan Bureau of Statistics (PBS).
15. Hansen, M. H., Hurwitz, W. N., and Madow, W. G. (1993) *Sampling Survey Methods and Theory*, Vol. 1 and II, Wiley.

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:

1. Baltagi, B. H. (1999). "*Econometrics*", 2nd Edition, Springer Varlog.
2. Draper, N.R. and Smith, H. (2004). "*Applied Regression Analysis*", John Wiley, New York.
3. Gujarati, D. (2004). "*Basic Econometrics*", John Wiley, New York.
4. Guttman, I. (1980); "*Linear Models: An Introduction*", John Wiley, New York.
5. Johnston, J. and Di. Nardo, J., (1997). "*Econometric Method*", 4th Edition, McGraw Hill, New York.
6. Koutsoyiannis, A. (1980), "*Theory of Econometrics*", Macmillan.

7. Montgomery, D.C., and Peck E.A. (1992). "*Introduction to Linear Regression Analysis*", 2nd Edition. John Wiley and sons Inc. New York
8. Wonnacot, T.H. and Wonnacot R.J. (1998). "*Econometrics*", John Wiley, New York

STAT- 306: Design and Analysis of Experiments-II

Factorial Experiments: 2^k , 3^k 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:

1. Boniface, D.R. (1995). *Experimental Design & Statistical Methods*, Chapman & Hall.
2. Clarke, G.M. (1994). "*Statistics & Experimental Design*". Edward Arnold.
3. Clarke, G.M., and Kempton, R.E. (1997), "*Introduction to the Design & Analysis of Experiments*", Edward Arnold.
4. Das, M.N.and Giri, N.C, (1986). "*Design and Analysis of Experiments*", John Wiley, New York.
5. Gomez, K.A., and Gomez, A.A. (1984). "*Statistical Procedures for Agricultural Research*", 2nd Edition, John Wiley, New York.
6. Giesbrecht, F. G., Gompertz, M. L. (2004) Planning, Construction, and Statistical Analysis of Comparative Experiments. Wiley.
7. Harold, R. L (1992). "*Analysis of Variance in Experimental Design*". Springer Verlag:
8. Hicks, C.R. (1982). "*Fundamental Concepts in Design and Analysis of Experiments*"; Saunders
9. Maxwell, S.E. and Delaney, H.D. (1990). *Designing Experiments and Analysis of Data. A Model Comparison Perspective*. Belmont and Wadason.

10. Mead, R., Gilmour, S., and Mead, A. (1990) *Statistical Principles for the design of experiments: Applications to real experiments*. Cambridge University Press, Cambridge.
11. Montgomery, D.C. (2000). "*Design and Analysis of Experiments*", John Wiley, New York
12. Myers, R.H. and Montgomery, D.C. (1995). "Response Surface Methodology; Process & Product Optimization Using Design", John Wiley
13. Steel, G. D., Terrie, and Dickey A. (1997). "Principles and Procedures of Statistics: A Biometrical Approach" 3rd Edition, McGraw-Hill, New York

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, Intercensal 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

1. Bogue, D.J. Arriagu, E.E., Anderson, D.L. (1993), "*Readings in Population Research Methodology*", Vol. I-VIII, United Nations Fund; Social Development Centre, Chicago.
2. Hinde, A., (1998). "*Demographic Method*", Arnold New York.
3. Impagliazo, J. (1993), "*Deterministic Aspects of Mathematical Demography*", Springer Verlag New York.
4. Jay Weinstein, Vijayan, K. Pillai, (2001) "*Demography: The Science of Population*". Allyn & Bacon.1.

5. Keyfitz, N. (1983) "*Applied Mathematical Demography*", Springer Verlag N.Y.
6. Palmore, J.A; Gardner, R.W. (1994), "*Measuring Mortality Increase*"; East West Centre, Honolulu.
7. Pollard, A.H., Yousaf, F & Pollard, G.M. (1982), "*Demographic Techniques*", Pergamon Press, Sydney.
8. Rukanuddin A.R. and Farooqi, M.N.I., (1988), "*The State of Population in Pakistan – 1987*", NIPS, Islamabad.
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.
11. Publications of population census organizations.
12. United Nations (1990), "*World Population Monitoring 1989*", UNFPA.
13. United Nations (1998), "*World Population Assessment*", UNFPA; New York.
14. United Nations (1996), "*Added years of Life in Asia*", ESCAP; U.N., Thailand.
15. Haupt, A., Kane, T. T., and Haub, C. (2011) PRB's Population Handbook.

STAT- 401: Statistical Inference-I

Estimation of Parameters, Properties of Estimators: unbiasedness, consistency, sufficiency, efficiency, Invariance, completeness. Cramer-Rao inequality, Rao-Blackwell and Lehmann - Scheffe Theorems, Methods of Estimation: Moments, Maximum likelihood, least-squares, minimum Chi-square and Bayes' method.

Pre-Requisite: STAT-302

Recommended Books:

1. Bickel, P.J., and Doksum, K.A. (2005), *Mathematical Statistics*, Vol I, Prentice Hall, N.J., 2nd ed.
2. Hogg, R.V. and Craig, A.T. (1996). "*Introduction to Mathematical Statistics*". Prentice Hall, New Jersey.
3. Lindgren, B.W. (1998). "*Statistical Theory*". Chapman and Hall, New York.

4. Mood, A.M., Graybill, F.A. and Boss, D.C. (1997). "*Introduction to the Theory of Statistics*". McGraw Hill, New York.
5. Rao, C.R., (2009). "*Linear Statistical Inference and its Applications*", John Wiley, New York.
6. Rohatgi, V. K. (1984) *Statistical Inference*. Courier Dover Publications.
7. Stuart, A. and Ord, J.K. (2009). *Kendall's' "Advanced Theory of Statistics" Vol. II*. Charles Griffin, London.
8. Zacks, S. (1973), "*Parametric Statistical Inference*", John Wiley, New York.

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:

1. Afifi, A. A. and Clark Virginia (1984). *Computer Aided Multivariate Analysis*, Lifetime learning publications, Belmont California.
2. Anderson, T.W. (2003). *An Introduction to Multivariate Statistical Analysis*, John Wiley, New York.
3. Chatfield, C. and Collins, A.J. (1980). *Introduction to Multivariate Analysis*, Chapman and Hall, London.
4. Everett, B.J. (1974). *Cluster Analysis*, McGraw-Hill, New York.
5. Flurry B. (1997) *A First Course in Multivariate Statistics*, Springer Valerg, New York.
6. Hair, J.F., Anderson R.E., Jatham, R.L. and Black W.C., (1998). *Multivariate Data Analysis*, 5th ed. Pearson Education, Re print 2005, Asia edition.

7. Johnson, R.A. and Wichern, D.W. Applied Multivariate Statistical Analysis (6th ed.). Prentice Hall. London.
8. Joseph F. Hair Jr, William C. Black, Barry J. Babin, Rolph E. Anderson (2009). Multivariate Data Analysis (7th Edition), Pearson education Asia Edition.
9. Manly, B.F.J. (1994). Multivariate Statistical Methods, A Primer 2nd Edition, Chapman and Hall, London.
10. Mardia, K.V., Kent, J.T. and Bibby, J.M. (1979). Multivariate Analysis, Academic Press, London.
11. Morrison. F. (1990). Multivariate Statistical Methods, McGraw-Hill, New York.
12. Raykov, T. and Marcoulides, G. A. (2008) Introduction to Applied Multivariate Analysis. Tylor & Francis.
13. Rechner, A. C. (2002) Methods of Multivariate Analysis. Wiley.
14. Sharma, S. (1996), Applied Multivariate Techniques, John Wiley and Sons, New York.
15. Tabachnick, B.G and Fidell, L.S. (1996), Using Multivariate Statistics, 3rd ed. Harper Collins College Publishers.

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

Tests of Hypotheses: Simple and composite hypotheses, critical regions. Neyman-Pearson Lemma, power functions, uniformly most powerful tests. Deriving tests of Hypothesis concerning parameters in normal, exponential, gamma and uniform distributions, Randomized Tests, Unbiased tests, Likelihood ratio tests and their asymptotic properties. Sequential Tests: SPRT and its properties, A.S.N. and O.C. functions.

Pre-Requisite: STAT-401

Recommended Books:

1. Hogg, R.V. and Craig, A.T. (1996). *Introduction to Mathematical Statistics*. Prentice Hall, New Jersey.
2. Hirai, A. S. (2012) Estimation of Parameters. Ilmi Kitab Khana Lahore.

3. Lehman, E.L. (2008). "*Testing Statistical Hypotheses*". Springer - Volga, New York.
4. Lindgren, B.W. (1998). "*Statistical Theory*". Chapman and Hall, New York.
5. Mood, A.M. Gray Bill, F.A. and Boss, D.C. (1997). "*Introduction to the Theory of Statistics*". McGraw Hill, New York.
6. Rao, C.R., (2009). "*Linear Statistical Inference and its Applications*", John Wiley, New York.
7. Stuart, A and Ord, J.K. (2009). *Kendall's' "Advanced Theory of Statistics" Vol. II*. Charles Griffin, London.
8. Welish, A. H. (2011) *Aspects of Statistical Inference*. Wiley.
9. Zacks, S. (1973), "*Parametric Statistical Inference*", John Wiley, New York.

STAT- 422: RESEARCH PROJECT / INTERNSHIP

ELECTIVE COURSES

STAT- 405: Research Methodology

Definition of Research, Types of Research: Selection of Problem, Search of References, Formation of Hypothesis and Procedure for its Testing, Research Design, Planning of Experiments to Test Hypothesis Objectivity, Principles of Experimental Design, Steps in Experimentation, Designing Questionnaire, Collection of Data, Data Analysis to Determine, Functional Relationship Between Variables, Levels of Significance, Interpretation of Results, Components of Scientific Reports and Various Methods of Data, Presentation, Preparation of Scientific Reports, Publication Procedures. Qualitative Research: content analysis.

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:

1. Gimbal, J. and W.S. Acuter (1988) "MLA handbook for Writers of Research Papers", McGraw the Modern Language Association of America.
2. Hashmi, N. (1989) "Style Manual of Technical Writings", USAID/NARC, Islamabad.

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:

1. Bazarra, N.M., Jarvis J.J. and Sherali, H.D. (1990) "*Linear Programming and Network Flows*", John Wiley & Sons, 2nd ed.

2. Bronson, R. (1983). "Operations Research – Schaums' Outline Series" – McGraw-Hill.
3. Gupta, P.K. & Hira, D.S. (2008). "Operations Research". (7th ed.) S. Chand & Co., New Delhi.
4. Hillier, F.S. and Lieberman G. J. (2005). "Introduction to Operations Research", (8th ed.) Holden Day.
5. Ravindran, A., Philips, D.J and Silberg, J.J. (2007). "Operations Research: Principles and Practice" (2nd ed.) John Wiley.
6. Taha, H.A. (2002) Operations Research. Macmillan. London

STAT- 407: Stochastic Processes

Introduction, Generating Functions, Laplace Transforms, Difference Equations, Differential-Difference Equations, Introduction to Stochastic Processes. The Random Walk in one and two Dimensions, The Classical Gambler's Ruin Problem, Expected Duration of the Game

Markov Chains: Definition. Higher Transition Probabilities, Classification of States and Chains, Markov processes with Discrete State Space, Poisson Process and its Generalization, Pure Birth and Death Processes, Markov Processes with Discrete State Space (Continuous Time Markov Chains), Markov Processes with Continuous State Space. Introduction to Brownian motion

Recommended Books

1. Cox, D.R. and Miller H.D. (1984). "The Theory of Stochastic Processes", Chapman and Hall, London.
2. Grimmet G. and Stirzaker D. (2001): Probability and Random Processes, Oxford University Press.
3. Hole, P.G., Port, S. and Stone, C.L. (1984). "An Introduction to Stochastic Process", John Wiley, New York.
4. Karlin, S.A. and Taylor H.M. (1984). "A first course in Stochastic Process", Academic Press London.
5. Medhi, J. (1982), "Stochastic Processes", Wiley Eastern Ltd.
6. Ross, S. M. (2006). "Stochastic Process", John Wiley, New York.
7. Srinivasin, S.K. and Mehta, K.M. (1988). "Stochastic Processes". Tata McGraw-Hill.

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:

1. Achintya Haldar, Sankaran Mahadevan (2000). *Reliability Assessment Using Stochastic Finite Element Analysis*".
2. Crowder, M.J. (1994). "*Statistical Analysis of Reliability Data*".
3. Gertsbakh, I.B. (1989). "*Statistical Reliability Theory*". Marcel Decker. New York.
4. Gertsbakh, I. Reliability theory : with applications to preventive maintenance Publisher: New Delhi : Springer, 2009
5. Lawless, J.F. "*Statistical Model and Methods for Lifetime Data*".(2nd ed.)
6. Lee, J. Bain, Bain Bain, (1991). "*Statistical Analysis of Reliability and Life-Testing Models*".
7. Mann, N.R., Scheefer, R.E. and Singapoor walla, N.D. (1974). *Methods for Statistical Analysis of Reliability*, John Wiley & Sons.

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:

1. Andy, P, West M. and Harrison, P. J. (1994). Applied Bayesian Forecasting and Time Series Analysis, Chapman & Hall New York.
2. Bovas, A. and Johannes, L. (1983), Statistical Methods for Forecasting, John Wiley. New York
3. Box, G.E.P. and Jenkins, G.M., and Reinsel G. C. (2008) Time Series Analysis: Forecasting and Control, San Francisco.
4. Brock well P.J. and Davis R.A. (1991). Time Series Theory and Methods, Springer Verlag New York.
5. Chatfield, C. (1996). The Analysis of Time Series: An Introduction, Chapman and Hall, London.
6. Chatfield C. (2003): The Analysis of Time Series: An Introduction, Taylor & Francis, NY, USA.
7. Cox, D. R., Hinckley D.V. and Nielsen O.E.B. (1996). Time Series Models - In Econometrics, finances and other fields; Chapman & Hall, London.
8. Diggle, P.J. (1990), Time Series: A Biostatistical Introduction, Clarendon Press, Oxford.
9. Jonathan D. C. and Kung-Sik C. (2008): Time Series Analysis with Applications in R, Springer, USA.
10. Hamilton J. D. (1994): Time Series Analysis, Princeton University Press, UK.
11. Harvey, A.C. (1990). Forecasting Structural Time Series Models and the Calamander, Cambridge University Press, Cambridge.
12. Peter J. B and Richard A. D (2002): Introduction to Time Series and Forecasting, Second Edition, Springer, USA.
13. Priestley, M.B. (1981) Spectral Analysis and Time Series, Academic Press, London.

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:

1. Berger, J. O. (1985). "*Statistical Decision Theory & Bayesian Analysis*", Springer Verlag.
2. Blackwell, D. and Graphic, M.A. (1966). "*Theory of Games and Statistical Decision*", John Wiley, New York.

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:

1. Hamper, T.R. Brochette, E.M. Rousseau, P.J. and Satchel, W.A. (1986). "*Robust Statistics*", "*The approach Based on Influence functions*", John Wiley New York.
2. Hosmer D. W. and Lemeshow S. (2008): Applied Survival Analysis, Wiley Interscience, USA.
3. Huber, P.J. (1981). "*Robust Statistics*", John Wiley, New York.
4. Olive D. J. (2007): Applied Robust Statistics, Southern Illinois University Department of Mathematics.
5. Rousseau, P.J. and Leroy, A.M. (1987). "*Robust Regression and outlier detection*", John Wiley. New York.

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:

1. Hansen M.H. (1980). "*Progress and Problems in Survey Methods and Theory*". Illustrated by the work of U.S. Bureau of the Census, U.S. Department of Commerce; A Monograph.
2. NIPA (1962) "*Administrative uses of Statistics*", NIPA Res. Sr.No.2 Karachi.
3. Statistical Institute for Asia & Pacific SIAP (1984). "*Training of Trainers in Statistical Operations and Procedures*" Part-I, II UNDP, Tokyo.
4. Statistics Division (1979). "*Retrospect, Perspective and Prospect*", Islamabad.
5. Statistics Division, "*Activity Report*" (1988-89). Government of Pakistan, Islamabad.
6. Various Publications of PBS, State Bank of Pakistan, Ministry of Finance, etc.
7. Zarkovich S.S. (1966) "*Quality of Statistical Data, Food and Agricultural Organization*", The U.N. Rome.
8. Statistics Reorganization Act 2011

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:

1. Burkett, M. (1995). "*Analyzing Survival Data from Clinical Trials and Observational Studies*"; John Wiley New York.
2. Collett, D. (1994). "*Modeling Survival Data in Medical Research*". Chapman & Hall, London.

3. Cox, DR. and Oakes, D. (1984). "*Analysis of Survival Data*"; Chapman & Hall London.
4. Eland Johnson, R. C. and Johnson N. L. (1989), "*Survival Models & Data Analysis*". John Wiley N.Y.
5. Lee, E.T. (1992). "*Statistical Methods for Survival Data Analysis*"; John Wiley. N.Y.
6. Lee, E.T. (1997). "*Applied Survival Analysis*", John Wiley and Sons, New York.
7. Muller, R.G. and Xian Zhou (1996). "*Survival Analysis with long-term Survivors*", John Wiley. New York.
8. Parmer M.K.B. & Macklin D. (1995). "*Survival Analysis: A Practical Approach*"; John Wiley New York.
9. Turkey, J. (1987). "*Exploratory Data Analysis*", John Wiley, New York.

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:

1. Alfassi Z. B., Boger, Z. and Ronen, Y. (2005): *Statistical Treatment of Analytical Data*, Blackwell Science, USA.
2. Altman, G. (1991). "*Practical Statistics for Medical Research*". Chapman & Hall, London.
3. Ahmad, M., Ahmad, A., and Hanif, M. (2004) *Manual of Statistics for Medical Sciences*. ISOSS Publications Lahore.
4. Daniel, W.W. (2010). "*Biostatistics: A Foundation for the Health Sciences*", 6th Edition, John Wiley, New York.
5. Diggle, J. P., Liang, Kung-Yee and Zeger, S. L. (1996). "*Analysis of Longitudinal Data*", Clarendon Press, Oxford.
6. Dunn, G. and Everit, B. (1995). "*Clinical Biostatistics*", Edward Arnold, London.

7. Hanif M., Munir A. and Aftab M. A. (2006): Biostatistics for Health Students with Manual on Software Applications, ISOSS Publication.
8. Harris, E. K. and Albert, A. (1991). "*Survivorship Analysis for Clinical Studies*". Marcel Decker, New York.
9. Lawless, J. F. (1982). *Statistical Models and Methods for Life Time Data*. John Wiley, New York.
10. Lee, E.T. (1992). "*Statistical Methods for Survival Data Analysis*", 2nd Edition, John Wiley, New York.
11. Rosner, B. (2006). "*Fundamentals of Biostatistics*", Duxbury Press.
12. Shoukri, M. M. & Pause, C. A. (1999). "*Statistical Methods for Health Sciences*". 2nd Edition, CRC Press, Florida.
13. Zar, J. (2000). "*Biostatistical Analysis*", 5th Edition, John Wiley and Sons.
14. Zolman, J.F. (1993). "*Biostatistics: Experimental Design and Statistical Inference*", Oxford University Press, New York.

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

1. Benson and Smith, S.J. (1997). "*Data Warehousing, Data Mining*", and OLAP. McGraw-Hill.
2. Bramer M (2007): *Principles of Data Mining*. Springer-Verlag London Limited UK.
3. Breiman, L. Friedman, J.H. Olshen, R.A. and Stone, C.J. (1984). "*Classification and Regression Trees*" Wadsworth and Brooks/Cole.
4. Han, J., Kamber, J. Pei, J., and Burlington, M. A. (2012) Data mining: concepts and techniques. Haryana, India.
5. Han, J. and Camber, M. (2000). Data Mining; "*Concepts and Techniques*". Morgan Kaufmann.

6. Mitchell, T.M. (1997). *“Machine Learning”*. McGraw-Hill.
7. Rao C. R., Wegman E. J. & Solka J. L (2005): *Handbook of Statistics, Vol. 24: Data mining and data visualization*. Elsevier B.V., North Holland.
8. Ripley, B.D. (1996). *“Pattern Recognition and Neural Networks”*. Cambridge University Press.
9. Suh, S. C. (2012) Practical applications of data mining. Suh. Publisher
10. Tan P., Steinbach M. & Kumar V. (2006): *Introduction to Data Mining*. Addison Wesley, New York.

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:

1. Bowers, N.L. Gerber, H.U. Hickman, J.C. Jones, D.A. and Nesbitt, C.J. (1997). *“Actuarial Mathematics”*, Society of Actuarial, Ithaca, Illinois, U.S.A
2. Dkkson, M. R., Hardy, H, Wates (2009) Actuarial Mathematics for Life Contingent Risks. Cambridge.
3. Neill, A. (1977). *“Life Contingencies”*, Heineman.
4. Polard, B., John, H. (1980) Analysis of Mortality and Actuarial Statistics. Faculty & Institute of Actuarial Sciences U.K.

5. Spurgeon, E.T. (1972), "*Life Contingencies*", Cambridge University Press.

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:

1. Borowiak, D. S., Shapiro, A. F. (2003) *Financial and Actuarial Statistics: An Introduction*. CRC Press.
2. Bowers, N.L. Gerber, H.U. Hickman, J.C. Jones, D.A. and Nesbitt, C.J. (1986) "*Actuarial Mathematics*", Society of Actuaries, Ithaca, Illinois, U.S.A. Second Edition (1997).

3. Corazza, M. and Claudio, P. (2010) *Mathematical and Statistical Methods for Actuarial Sciences and Finance*. Springer.
4. Neill, A. (1977). "*Life Contingencies*", Heinemann.
5. Spurgeon, E.T. (1972). "*Life Contingencies*", Cambridge University Press.

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:

1. Bernard P Autor Zeigler, Herbert Praehofer, Tag Gon Kim (2000) *Theory of Modeling and Simulation*
2. Daniel P. M, Maynard T. (2006): *Mathematical Modeling and Computer Simulation*, Thomson Brooks/Cole
3. Fishman, G.S. (1996). *Monte Carlo: "Concepts, Algorithms, and Applications"*, (Springer).
4. Ripley, B.D. (1987) "*Stochastic Simulations*" (Wiley)
5. Ross, S.M. (2002). "*Simulation*" (Third Edition) (Academic)
6. Rubinstein, R.Y. (1981). "*Simulation and the Monte Carlo Method*", (Wiley).
7. Velten, K. (2009): *Mathematical modeling and simulation*, Wiley VCH, Germany

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:

1. Alan Agresti (2012) *Categorical Data Analysis* (3rd edition). Wiley.
2. Alan Agresti (2007) *An Introduction to Categorical Data Analysis* (2nd edition). John Wiley & Sons.
3. Chap T. Le (1998) *Applied Categorical Data Analysis*. Wiley
4. Collett D. (2003) *Modeling Binary Data*. Chapman and Hall/CRC.
5. Hosmer D. W., Lemeshow S. (2004) *Applied Logistic Regression*. John Wiley & Sons.
6. Lloyd C. J. (1999) *Statistical Analysis of Categorical Data*. Wiley
7. Powers D. A., and Yu Xie (2008) *Statistical Methods for Categorical data analysis* (2nd edition). Emerald Group publishing.
8. Ronald C. (1997) *Log-linear models and logistic regression* (2nd edition). Springer.
9. Simonoff J. S. (2003) *Analyzing Categorical Data*. Springer

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:

1. Berger, J.O., *Statistical Decision Theory and Bayesian Analysis* (2nd Ed.), New York, Springer Verlag (1985).
2. Bernardo, J. M. & Smith, A.F.M., *Bayesian Theory*, John Wiley, New York (1994).
3. Box, G.E. P & Tiao, G. C. *Bayesian Inference in Statistical Analysis*, Reading Addison-Wesley (1973).

4. Introduction to Bayesian Statistics by William M. Bolstad (2004)
5. Lee, P.M. Bayesian Statistics, an Introduction, Oxford University Press, New York (1991).
6. O.Hagan A. Kendall's Advanced Theory of Statistics (Vol.2B), Bayesian Inference, Cambridge, The University Press (1994).

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:

1. Banks, J. (1989). "*Principles of Quality Control*". John Wiley, New York.
2. Feigenbaum, A.V. (1986). "*Total Quality Control*". McGraw-Hill, New York.
3. Juran, J.M. and Guyana, F.K. (1988). "*Juan's Quality Control Handbook*". McGraw Hill New York.
4. Miltag H. J. and Rinne H. (1993). "*Statistical Methods of Quality Assurance*", Chapman & Hall, London.
5. Montgomery, D.C. (2013). "*Introduction to Statistical Quality Control*". McGraw Hill, New York.
6. Nelson, W. (1990). "*Accelerated Testing*". John Wiley, New York.
7. Ryan, T.P. (1989). "*Statistical Methods for Quality Improvement*". John Wiley, New York.

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.

Course Contents

Basics of Grammar
Parts of speech and use of articles
Sentence structure, active and passive voice
Practice in unified sentence
Analysis of phrase, clause and sentence structure
Transitive and intransitive verbs
Punctuation and spelling

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**

1. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 1, third edition, Oxford University Press, 1997. ISBN 0194313492
2. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 2, third edition, Oxford University Press, 1997. ISBN 0194313506

b) Writing

1. Writing Intermediate by Marie-Christine Boutin, Suzanne Brinand and Françoise Grellet., Oxford Supplementary Skills, Fourth Impression, 1993. ISBN 0 19 435405 7 Pages 20-27 and 35-41.

c) Reading/Comprehension

1. Reading Upper Intermediate Brain Tomlinson and Rod Ellis, Oxford Supplementary Skills, Third Impression, 1992. ISBN 0 19 453402 2

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
 - 1. Practical English Grammar by A.J. Thomson and A.V. Martinet, Exercises 2, third edition, Oxford University Press, 1986. ISBN 0 19 431350 6
- b) Writing
 - 1. Writing. Intermediate by Marie-Christine Boutin, Suzanne Brinand and Françoise Grellet. Oxford Supplementary Skills. Fourth Impression 1993. ISBN 019 435405 7 Pages 45-53 (note taking).
 - 2. Writing.Upper-Intermediate by Rob Nolasco. Oxford Supplementary Skills. Fourth Impression 1992. ISBN 0 19 435406 5 (particularly good for writing memos, introduction to presentations, descriptive and argumentative 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
 - 3. Study Skills by Richard Yorke.

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

1. Writing Advanced by Ron White, Oxford Supplementary Skills. Third Impression 1992, ISBN 0 19 435407 3 (particularly suitable for discursive, descriptive, argumentative and report writing)
2. College Writing Skills by John Langan. McGraw-Hill Higher Education. 2004.
3. Patterns of College Writing (4th edition) by Laurie G. Kirszner and Stephen R. Mandell. St. Martin's Press.

b) Presentation Skills

c) Reading

The Mercury Reader, a Custom Publication, Compiled by northern Illinois University, General Editors: Janice Neulib; Kathleen Shine Cain; Stephen Ruffus and Maurice Scharon. (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

- a. Ideological rationale with special reference to Sir Syed Ahmed Khan, Allama Muhammad Iqbal and Quaid-e-Azam Muhammad Ali Jinnah.
- 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:

1. Burki, Shahid Javed. *State & Society in Pakistan*, The Macmillan Press Ltd 1980.
2. Akbar, S. Zaidi. *Issue in Pakistan's Economy*. Karachi: Oxford University Press, 2000.
3. S.M. Burke and Lawrence Ziring. *Pakistan's Foreign policy: An Historical analysis*. Karachi: Oxford University Press, 1993.
4. Mehmood, Safdar. *Pakistan Political Roots & Development*. Lahore, 1994.
5. Wilcox, Wayne. *The Emergence of Bangladesh.*, Washington: American Enterprise, Institute of Public Policy Research, 1972.
6. Mehmood, Safdar. *Pakistan Kayyun Toota*, Lahore: Idara-e-Saqafat-e-Islamia, Club Road, nd.
7. Amin, Tahir. *Ethno - National Movement in Pakistan*, Islamabad: Institute of Policy Studies, Islamabad.
8. Ziring, Lawrence. *Enigma of Political Development*. Kent England: WmDawson & sons Ltd, 1980.
9. Zahid, Ansar. *History & Culture of Sindh*. Karachi: Royal Book Company, 1980.
10. Afzal, M. Rafique. *Political Parties in Pakistan*, Vol. I, II & III. Islamabad: National Institute of Historical and cultural Research, 1998.
11. Sayeed, Khalid Bin. *The Political System of Pakistan*. Boston: Houghton Mifflin, 1967.
12. Aziz, K.K. *Party, Politics in Pakistan*, Islamabad: National Commission on Historical and Cultural Research, 1976.
13. Muhammad Waseem, *Pakistan under Martial Law*, Lahore: Vanguard, 1987.
14. Haq, Noor ul. *Making of Pakistan: The Military Perspective*. Islamabad: National Commission on Historical and Cultural Research, 1993.

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 Holly 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 Holly 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 Umayyads
- 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) Hameed ullah Muhammad, "Emergence of Islam", IRI, Islamabad
- 2) Hameed ullah Muhammad, "Muslim Conduct of State"
- 3) Hameed ullah Muhammad, 'Introduction to Islam
- 4) Mulana Muhammad Yousaf Islahi,"
- 5) Hussain Hamid Hassan, "An Introduction to the Study of Islamic Law" leaf Publication Islamabad, Pakistan.
- 6) Ahmad Hasan, "Principles of Islamic Jurisprudence" Islamic Research Institute, International Islamic University, Islamabad (1993)
- 7) Mir Waliullah, "Muslim Jurisprudence and the Quranic Law of Crimes" Islamic Book Service (1982)
- 8) H.S. Bhatia, "Studies in Islamic Law, Religion and Society" Deep & Deep Publications New Delhi (1989)
- 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

Swokowski EW, *Fundamentals of Algebra and Trigonometry* (6th edition), 1986, 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:

Anton H, Bevens I, Davis S, *Calculus: A New Horizon* (8th edition), 2005, John Wiley, New York

Stewart J, *Calculus* (3rd edition), 1995, Brooks/Cole (suggested text)
Swokowski EW, *Calculus and Analytic Geometry*, 1983, PWS-Kent Company, Boston

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:

Abraham S, *Analytic Geometry*, Scott, Freshman and Company, 1969
Kaufmann JE, *College Algebra and Trigonometry*, 1987, PWS-Kent Company, Boston

Swokowski EW, *Fundamentals of Algebra and Trigonometry* (6th edition), 1986, PWS-Kent Company, Boston

Annexure “E”

COURSE FOR NON-STATISTICS MAJOR IN SOCIAL SCIENCES

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

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

Number, Collection of primary and secondary data, Sources, Editing of Data, Exercises.

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, Histogram, 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

- 1 Walpole, R. E. 1982. "Introduction to Statistics", 3rd Ed., Macmillan Publishing Co., Inc. New York.
- 2 Muhammad, F. 2005. "Statistical Methods and Data Analysis", Kitab Markaz, Bhawana Bazar Faisalabad.

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:-

Semester	No. of Subjects	Credit Hours	Total Credit Hours
1 st	4	3	12
2 nd	4	3	12
3 rd + 4 th	Thesis / Research Work		12
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.)

Stat-716	Advanced Distribution Theory	(3 cr.hrs.)
Stat-717	Inference in Stochastic Processes	(3 cr.hrs.)
Stat-718	Advanced Bayesian Inference	(3 cr.hrs.)
Stat-719	Optimization Techniques	(3 cr.hrs.)
Stat-720	Statistical Ecology	(3 cr.hrs.)
Stat-721	Medical Statistics	(3 cr.hrs.)
Stat-722	Analysis of Clinical Trials	(3 cr.hrs.)
Stat-723	Financial Stochastic Models	(3 cr.hrs.)
Stat-724	Statistical Genetics	(3 cr.hrs.)
Stat-725	Generalized Linear Models	(3 cr.hrs.)
Stat-726	Repeated Measure Analysis	(3 cr.hrs.)
*Stat-727	Decision Trees	(3 cr.hrs.)
*Stat-728	Theory of Mixed Linear Models	(3 cr.hrs.)
*Stat-729	Advanced Operations Research	(3 cr.hrs.)
*Stat-730	Multilevel Modeling	(3 cr.hrs.)
*Stat-731	Environmental Statistics	(3 cr.hrs.)
*Stat-731	Advanced Statistical Methods in Quality Control	(3 cr.hrs.)

* 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:

1. Bhat, B.R. (1985), Modern Probability Theory, Wiley Eastern.
2. Billingsley, P. (1986), Probability and Measure, John Wiley and Sons.
3. Feller, W. (1969), Introduction to Probability and its Applications, Vol-II, Wiley Eastern Ltd.
4. Gnedenko, B.V. (1988), Probability Theory, Mir Pub.
5. Loeve, M. (1978), Probability Theory, 4th ed., Springer Verlag.
6. Stuart A. and Ord J. K. (1998) Advanced Theory of Statistics, Volume I: Distribution Theory. 6th Ed, Edward Arnold

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

Introduction to linear models with examples, Review of Matrix Algebra, Random vectors, multivariate normal distribution and quadratic forms, General linear model: Linear least squares problem, Model fitting, extra sums of squares principle, Model checking and model selection, Generalized least squares, Statistical inference for the general linear model, Sequential and hierarchical sums of squares, Sensitivity of assumptions in general linear model :Under-fitting, over-fitting, Misspecification of covariance structure, and non-normality, Fixed, random effect, and mixed models, A short introduction to generalized linear model.

Recommended Books:

1. Alvin C. R., and G. Bruce S. (2008) *Linear Models in Statistics* (2nd edition). John Wiley & Sons.
2. Bingham N. H. and Fry J. M. (2010) *Regression: Linear Models in Statistics*. Springer.
3. Graybill, F.A. (1976). *Theory and Application of the Linear Model*. Duxbury Press.
4. Julian J. Faraway (2002) *Linear Models with R*
5. Michael, K., Nachtsheim, C., Neter, J., and Li, W. (2004) *Applied Linear Statistical Models: 5th edition*. McGraw-Hill
6. Rao C. R., Toutenberg, H., Shalabh, and Heumann, C. (2007). *Linear Models and Generalizations: Lest Squares and Alternatives*. Springer.
7. Rencher, A.C. (2000). *Linear Models in Statistics*. Wiley.
8. Searle, S.R. (1971). *Linear Models*. Wiley.
9. Stapleton, J.H. (1995). *Linear Statistical Models*. Wiley.
10. Steven J. J., and Fredrick C. T. (2005) *Introduction to Linear Models and Statistical Inference*, Wiley

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:

1. Cox, D.R. and Hinkley, D.V. (1974). *Theoretical Statistics*. Chapman and Hall, London.
2. Freund, J. E. (1997). *Mathematical Statistics*. Prentice-Hall, New Jersey.

3. Hogg, R., Elliot A. Tanis, Robert V. Hogg, Elliot. (2000). *Probability and Statistical Inference*. Prentice Hall (6th Edition).
4. Hogg, R.V. and Craig, A.T. (1996). *Introduction to Mathematical Statistics*. Prentice Hall, New Jersey.
5. Lehman, E.L. (1983). *Theory of Point Estimation*. John Wiley and Sons.
6. Lehmann, E.L. (1997). *Testing Statistical Hypotheses*. Springer - Valag, New York.
7. Lindgren, B.W. (1998). *Statistical Theory*. Chapman and Hall, New York.
8. Mood, A.M. Graybill, F.A. and Boss, D.C. (1997). *Introduction to the Theory of Statistics*. McGraw-Hill, New York.
9. Rao, C.R., (1973). *Linear Statistical Inference and its Applications*. John Wiley, New York.
10. Rohatgi, V.K. (1984). *Statistical Inference*, John Wiley and Sons.
11. Silvey, S. D. (1975). *Statistical Inference*. Chapman and Hall.
12. Stuart,A and Ord J.K. (1998). *Kendalls' Advanced Theory of Statistics Vol. II*. Charles Griffen, London.
13. Zacks, S. (1973). *Parametric Statistical Inference*. John Wiley, New York.

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:

1. Barnett, V. and Lewis, T. (1984). *Outlier in Statistical data*, 2nd Edition, John Wiley and Sons New York.
2. Belsley, D.A.; Kuh, E. and Welsch, R.E. (1980). *Regression Diagnostic: identifying influential data and sources of collinearity*.
3. Draper, N.R. and Smith H. (1998). *Applied Regression Analysis*. 3rd edition. John Wiley and Sons New York.
4. Rawlings, P.J. (1987). *Applied regression analysis, A research tool*. Wadsworth & Brook/Cole, Pacific Grave, California.
5. Rousseew, P.J. and Leroy, A. M. (1987). *Robust regression and outlier detection*. John Wiley and Sons New York.

6. Wetherill, G. B. (1986). *Regression Analysis with applications*. John Wiley and Sons New York

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:

1. Boniface, D.R. (1995). *Experiment Design & Statistical Methods*, Chapman & Hall.
2. Cochran, W.G. and Cox, G.M. (1992), *Experimental Design*, Wiley International.
3. Dey, A. (1986), *Theory of Block Designs*, Wiley Eastern Ltd. New Delhi
4. Harold, R. L (1992) *Analysis of Variance in Experimental Design*. Springer Verlag:
5. Hunter, B. and Hunter, W. G. (2005) *Statistics for Experimenters: Design, Innovation and Discovery*. Wiley.
6. John, J.A. (1987), *Cyclic Design*, Chapman and Hall, London
7. Kenward, M.G. and Jones, B. (1989), *Design and Analysis of Cross-over Trails*.
8. Khuri, A. I. and Cornell, J. A. (2001) *Response Surfaces; design and Analysis*, 2nd ed, CRC Press, USA.
9. Maxwell, S.E. and Delaney, H.D. (1990). *Designing Experiments and Analysis of Data. A model comparison perspective*. Belmont and Wadason.
10. Mead, R. (1988). *The Design of Experiments*. Cambridge University Press, Cambridge.
11. Montgomery D.C. (2012). *Design and Analysis of Experiments*, John Wiley, NY.
12. Myers, R.H. and Montgomery, D.C. (1995). *Response Surface Methodology; Process & Product Optimization using design*, John Wiley.

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:

1. Afifi, A. A. and Clark Virginia (1984). *Computer Aided Multivariate Analysis*, Lifetime learning publications, Belmont California.
2. Anderson, T.W. (2003). *An Introduction to Multivariate Statistical Analysis*, John Wiley, New York.
3. Chatfield, C. and Collins, A.J. (1980). *Introduction to Multivariate Analysis*, Chapman and Hall, London.
4. Everett, B.J. (1974). *Cluster Analysis*, McGraw-Hill, New York.
5. Flurry B. (1997) *A First Course in Multivariate Statistics*, Springer Valerg, New York.
6. Hair, J.F., Anderson R.E., Jatham, R.L. and Black W.C., (1998). *Multivariate Data Analysis*, 5th ed. Pearson Education, Re print 2005, Asia edition.
7. Johnson, R.A. and Wincher, D.W. (2004). *Applied Multivariate Statistical Analysis*. Prentice Hall. London.
8. Manly, B.F.J. (1994). *Multivariate Statistical Methods*, A Primer 2nd Edition, Chapman and Hall, London.
9. Mardia, K.V., Kent, J.T. and Bibby, J.M. (1979). *Multivariate Analysis*, Academic Press, London.
10. Morrison. F. (1990). *Multivariate Statistical Methods*, McGraw-Hill, New York.
11. Sharma, S. (1996), *Applied Multivariate Techniques*, John Wiley and Sons, New York.
12. Tabachnick, B.G and Fidell, L.S. (1996), *Using Multivariate Statistics*, 3rd ed. Harper Collins College, Publishers.

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 Tets, 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

Model evaluation and Testing: Residual analysis, Goodness of fit, Hypothesis Tests.

Duration data: Basic concepts of duration analysis, Hazard and Survivor Functions, Probability distributions for duration data, Exponential, PCE and Weibull Models. The relationship between counts and durations: Renewal processes, Specification and estimation of continuous time single-spell duration models, The Proportional Hazards Model, The mixed proportional hazard model. Competing risk models

Recommended Books:

1. Colin, A. C., & Trivedi, K. P. (2010). *Microeconometrics Using Stata*, Edition 2. Stata Press: Texas, USA .
2. Colin, A. C., & Trivedi, K. P. (2013). *Regression Analysis of Count Data*, 2nd Edition, Econometric Society Monograph, Cambridge University Press: Cambridge, UK. Econometrics, Volume V, North Holland, Amsterdam.
3. Hilbe, M. J. (2011). *Negative Binomial Regression. 2nd edition*, Cambridge University Press: Cambridge, UK.
4. Lancaster, T. (1990). The Econometric Analysis of Transition Data, Cambridge multiple durations, in J.J. Heckman and E. Leamer, editors, Handbook of University Press.
5. Van den Berg, G. J. (2001). Duration models: Specification, identification, and
6. Winkelmann, R. (2010). *Econometric Analysis of Count Data*. Springer Verlag: Berlin Heidelberg.

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:

1. Anderson, T., The Statistical Analysis of Time-Series, John Wiley and Sons. (1976).
2. Asteriou, D. (2006), Applied Econometrics, Palgrave Macmillan, New York
3. Box, G.E.P. and Jenkins G.M., Time-Series Analysis: Forecasting and Control 3rd Ed., Prentice Hall, Englewood Cliffs, N.J. USA, (1994).
4. Chatfield C. (2003) The Analysis of Time Series-An introduction. Tylor & Francis, NY, USA.
5. Enders, W. (1995), Applied Econometric Time Series, New York: John Willy & Sons Inc.
6. Enders, Walter, Applied Econometric Time Series, John Wiley and Sons, Inc. USA, (1995).
7. Jonathan D. C. and Kung-Sik C. (2008): Time Series Analysis with Applications in R, Springer, USA.
8. Gujarati, N. D. and Sangeetha (2007), Basic Econometrics, TATA McGraw – Hill, Companies 4th – Edition
9. Hamilton J. D. (1994), Time Series Analysis, Princeton University Press, UK
10. Harvey, H.C., Time Series Models, Halstead Press, New York. USA, (1993).
11. Kirchgassner, G. and Jurgen Wolters (2007), Introduction to Modern Time Series Analysis, Springer Berlin Heidelberg New York
12. Lutkepohl, H. and Markus Kratzig (2004), Applied Time Series Econometric, Cambridge University Press, New York.
13. Maddala, G. S. and Kim, I-M. (1998), Unit Roots, Cointegration and Structural Change, Cambridge University Press
14. Ostram C.W., Time Series Analysis: Regression Techniques Sage Publications, Beverly Hills, C.A. USA, (1978).
15. Peter J. B and Richard A. D (2002): Introduction to Time Series and Forecasting, Second Edition, Springer, USA.
16. Warner R.M., Spectral Analysis of Time Series data. Guilford Press New York, USA, (1998).

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:

1. Alan Agresti (2002) *Categorical Data Analysis* (2nd edition). John Wiley & Sons.
2. Alan Agresti (2007) *An Introduction to Categorical Data Analysis* (2nd edition). John Wiley & Sons.
3. Alan Agresti (2010) *Analysis of ordinal categorical data* (2nd edition). John Wiley & Sons.
4. Anderson E. B. (1994) *The Statistical Analysis of Categorical Data*. Springer – Verlag.
5. Bishop Y. M., Fienberg S. E., Holland P. W. (2007) *Discrete Multivariate Analysis*. Springer.
6. Chap T. Le (1998) *Applied Categorical Data Analysis*. Wiley
7. Collett D. (2003) *Modeling Binary Data*. Chapman and Hall/CRC.
8. Fienberg S. E. (2007) *The Analysis of Cross-Classified Categorical Data*. Springer
9. Fleiss J. L., Levin, B., Paik M. C., (2004) *Statistical Methods for Rates and Proportions*. Wiley
10. Hosmer D. W., Lemeshow S. (2004) *Applied Logistic Regression*. John Wiley & Sons.
11. Lloyd C. J. (1999) *Statistical Analysis of Categorical Data*. Wiley
12. McCullagh P., and Nelder J. A. (1989) *Generalized Linear Model*. Chapman & Hall
13. Powers D. A., and Yu Xie (2008) *Statistical Methods for Categorical data analysis* (2nd edition). Emerald Group publishing.
14. Ronald C. (1997) *Log-linear models and logistic regression* (2nd edition). Springer.
15. Simonoff J. S. (2003) *Analyzing Categorical Data*. Springer

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:

1. Copi, I.M. (1986), Introduction to Logic, 7th ed. Macmillan Publishing Co.
2. Goodde & Hatt (1991), Methods in Social Research, McGraw Hill.
3. Hurley, P.J. (1988). A Concise Introduction to Logic, 3rd ed. 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 unequal 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:

1. Cochran, W.G. (1996). *Sampling Techniques*. John Wiley and Sons, New York.
2. Des Raj and Chandhok, P. (1998), *Sample Survey Theory*. Narosa Publishing House, New Delhi.
3. Des Raj. (1998). *Design of Sample Survey*. McGraw Hill, New York.
4. Kish, L. (1992). *Survey Sampling*. John Wiley, New York.
5. Lessler, J.T. and Kalskeek, W.D. (1992). *Non-Sampling Errors in Surveys*. John Wiley and Sons.
6. Lohr, S.L. (1999). *Sampling: Design and Analysis*. Duxbury Press.

7. Mukhopadhyay, P. (2005). *Theory and Methods of Survey Sampling*. Prentice-Hall of India.

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

Lebesgue measure: Introduction, outer measure, measurable sets and Lebesgue measure, a non-measurable set. Measurable functions. Lebesgue Integral, the Riemann integral of a bounded function over a set of finite measure. The integral of a non-negative function, The general Lebesgue. General measure and integration, measure space, measure functions, integration, general convergence theorems, signed measure, Hahn decomposition theorem, Outer measure and measurability, The extension theorems, Convergence in measures. Some related topics: the L^p space, Holder and Minkowski inequalities, convergence and completeness, bounded linear functional on L^p space Riesz representation theorem.

Recommended Books:

1. Barru, G.D. (1981), *Measure Theory and Integration*, Ellis, Harwood Ltd.
2. Carlos S.K. (2007): *Gulf professional publishing measure theory*, John Wiley and sons.
3. Dipak Chatterjee (2002): *Real Analysis*, Prentice Hall New Delhi.
4. Folland, G.B. (1984), *Real Analysis-Modern Techniques and their Applications*, John Wiley and Sons.
5. Gupta S. L. and Gupta N.R. (2003): *Principles of real analysis*, Pearson.
6. Khan, A.R. (1993) *Introduction to Lebesgue Integration*, Illmi Kitab Khana, Lahore.
7. Malempati M.R. (2004): *Measure theory and integration*, Marcel Dekker.
8. Royden, H.L. (1968) *Real Analysis*, Collier Macmillan Co. New York.
9. Rudin, W. (1980) *Real and Complex Analysis*, McGraw Hill.

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

Basic Concepts, Censoring, Types of Censoring, Survival Functions, Relationship between Survival, Hazard and Density Functions, Survival Curves, Estimation of Survivorship Functions for Different Parametric Distributions, Non- Parametric Methods of Estimating Survival Functions, Non- Parametric Methods for Comparing Survival Distributions, Some Well-Known Survival Distributions and their Applications, Estimation Procedure for Parametric Survival Distributions without Covariates, Graphical Method for Survival Distribution Fitting, Test of Goodness of Fit

and Distribution Selection, Parametric Methods of Comparing Two Survival Distributions, Parametric Methods for Regression Model Fitting and Identification of Prognostic Factors, Identification of Prognostic Factors related to Survival Time: Cox Proportional Hazard Model, and Non Proportional Hazard models.

Recommended Books:

1. Birkett, M. (1995). *Analyzing Survival Data from Clinical Trials and Observational Studies*, John Wiley: New York.
2. Cleves, M., Gould, W., Gutierrez, R., & Marchenko, Y. (2010). *An Introduction to Survival Analysis Using Stata*, Third Edition, Stata Press, Texas:USA.
3. Collet, D. (2003). *Modeling Survival Data in Medical Research*, Chapman and Hall: London.
4. Hosmer, W. D., & Lemeshow, S. (2008). *Applied Survival Analysis: Regression Modeling of Time to Event Data*. 2nd edition Wiley-Interscience, Hoboken: New Jersey.
5. Klein, J. P., & Moeschberger, M. L. (2010). *Survival Analysis: Techniques for Censored and Truncated Data (Statistics for Biology and Health)*. Springer, New York: USA.
6. Lee, E.T. (1992). *Statistical Methods for Survival Data Analysis*, John Wiley, New York.
7. Muller, R.G., and Xian, Z. (1996). *Survival Analysis with long term Survivors*, John Wiley: New York.
8. Parmer, M. K. B. & Maclin, D. (1995.) *Survival Analysis: A practical Approach*, John Wiley: New York.

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

Probability generating functions, compound distributions, simple random walk, branching processes, Markov process, discrete and continuous time Markov chains, birth-death process, immigration and emigration process, immigration-death processes, renewal processes, Markov renewal process, Ergodic theorem, Gaussian processes and Brownian motion.

Recommended Books:

1. Beament, G.R.. *Introductory Applied Probability*.
2. Cox, D.R. and Miller, H.D. (1965). *The Theory of Stochastic Process*, Chapman and Hall.
3. Feller, W. (1968) *An Introduction to Probability Theory and its Applications*, Vol-1, 3rd ed., John Wiley and Sons.

4. Melhi, J. (1982), Stochastic Processes, Wiley International Ltd.
5. Stirzaker, D.R. (1982), Probability and Random Processes, Oxford University Press, London

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

1. Bartlett, M. (1975), Statistical Analysis of Spatial Pattern, Chapman and Hall, London.
2. Cressie, N. (1987), Statistics of Spatial Data, John Wiley and Sons.
3. Griffith, D. (1988), Advanced Spatial Statistics, Kluwer, Bostan.
4. Ripley, B. (1988), Statistical Inference for Spatial Processes, John Wiley and Sons.
5. Upton, G. and Fingleton, B. (1985), Spatial Data Analysis by Example, Vol.1 & 2, John Wiley and Sons.

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:

1. Billingsely, P. (1986), Probability and Measure. 2nd ed. John Wiley and Sons.
2. Johnson, N.L. and Kotz, S. (1987), Continuous Univariate Distribution, Vol-1 & 2, John Wiley and Sons.
3. Stuart, A. and Ord, J.K. (1987), Kendall's Advanced Theory of Statistics, Vol-1, 5th ed. Chales Griffin and Co. Ltd.

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:

1. Adke, S.R. and Manjunath, S.M.(1984) An introduction to Finite Markov Processes, (Wiley Eastern).
2. Basawa, I.V. and Prakasa Rao, B.L.S.(1980) Statistical Inference for Stochastic Processes, (Academic Press).
3. Bhat, B.R.(2000) Stochastic models : Analysis and Applications, (New Age International Publishers).
4. Billingsley, P. (1962) Statistical Inference for Markov chains, (Chicago University Press).
5. Grimmet G. and Stirzaker D. (2001): Probability and Random Processes, Oxford University Press.
6. Guttorp, P. (1991) Statistical Inference for Branching Processes, (Wiley).
7. Guttorp, P.(1995) Stochastic Modelling for Scientific Data, (Springer).
8. Prakasa Rao, B.L.S. and Bhat, B.R. (1996) Stochastic Processes and Statistical Inference, New Age International Publisher.
9. Ross S.M. (2006): Stochastic Process.

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:

1. Berger, J.O., Statistical Decision Theory & Bayesian Analysis, Springer-Verlag, New York, (1985).
2. Bernardo J. M. & Smith A. F. M., Bayesian Theory, John Wiley and sons, New York, (2008).
3. Lee P.M., Bayesian Statistics, Oxford University Press, New York, (2004).
4. O'Hagan, A. Kendall's, Advanced Theory of Statistics (V2B) Bayesian Inference, University Press: Cambridge, (1994).

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:

1. Abhijit G. (2003): Simulation-Based Optimization: Parametric Optimization Techniques and Reinforcement Learning, Springer-Verlag New York.

2. Hadley,G. (1987) Linear Programming.
3. Kambo, N.S.(1991) Mathematical Programming Techniques Affiliated East-West Press Pvt.Ltd.)
4. Onwuolu, Godfry C., and Babu, B. V. (2004) New Optimization Techniques in Engineering. Springer.
5. Taha, H.A.(2012) Operations Research. Macmillan

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

Population Dynamics: One species - exponential, logistic and Gompertz models. Two species - competition, coexistence, predator - prey oscillation, Lotka - Volterra equations, isoclines. Leslie matrix model for age structured populations. Survivorship curves - constant hazard rate, monotone hazard rate and bath-tub shaped hazard rates. Population density estimation: Capture- recapture models, nearest neighbor models, line transect sampling. Ecological Diversity: Simpson's index, Shannon – Weaver index, Diversity as average rarity. Optimal Harvesting of Natural Resources, Maximum sustainable yield, tragedy of the commons. Game theory in ecology: Concept of Evolutionary stable strategy, its properties, simple cases such as Hawk-Dove game. Foraging Theory: Diet choice problem, patch choice problem, mean variance tradeoff.

Recommended Books:

1. Clark, C.W.(1976) Mathematical bio-economics : the optimal management of renewable resources (Wiley)
2. Gore A.P. and Paranjpe S.A.(2000) A Course on Mathematical and Statistical Ecology, Kluwer Academic Publishers.
3. Maynard Smith J. (1982) Evolution and the theory of games (Cambridge University Press)
4. Pielou, E.C.(1977) An Introduction to Mathematical Ecology (Wiley)
5. Seber, G.A.F.(1982) The estimation of animal abundance and related parameters 2nd Ed. (C.Griffin)
6. Stephens D.W. & Krebs, J. R. (1986) Foraging Theory (Princeton University Press).

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.
2. Alfassi Z. B., Boger, Z. and Ronen, Y. (2005): Statistical Treatment of Analytical Data, Blackwell Science, USA.
3. Brookemeyer and Gail: AIDS Epidemiology: A Quantitative Approach
4. Clayton and Hills: Statistical methods in Epidemiology.
5. Diggle, Liang and Zeger : Analysis of longitudinal data
6. Hanif M., Munir A. and Aftab M. A. (2006): Biostatistics for Health Students with Manual on Software Applications, An ISOSS Publication.
7. Jerald F. L. (2003): Statistical Models and Methods for Lifetime Data, Joh Wiley.
8. Piantadosi: Clinical trials
9. Rosner B. (2006): Fundamentals Of Biostatistics, Thomson Higher Education, USA.
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.

Surrogate endpoints: selection and design of trials with surrogate endpoints, analysis of surrogate endpoint data. Meta-analysis of clinical trials

Recommended Books:

1. C. Jennison and B. W. Turnbull (1999). Group Sequential Methods with Applications to Clinical Trails, CRC Press.
2. Chow S.C. and Liu J.P. (2003): Design and Analysis of Clinical Trials: Concepts and Methodologies, 2nd Edition, Wiley.
3. E. Marubeni and M. G. Valsecchi (1994). Analyzing Survival Data from Clinical Trials and Observational Studies, Wiley and Sons.
4. J. L. Fleiss (1989). The Design and Analysis of Clinical Experiments. Wiley and Sons.
5. L. M. Friedman, C. Furburg, D. L. Demets (1998). Fundamentals of Clinical Trials, Springer Verlag.
6. S. Piantadosi (1997). Clinical Trials: A Methodological Perspective. Wiley and Sons.

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.

American and European options, Binomial model: One-step and two-step models, Binomial trees. Risk neutral valuation, Behaviour of stock prices: Conditional expectation, Martingale, Brownian Motion, Markov property, ITO Process, ITO Lemma, Black Scholes model: Distribution of returns, volatility, Black-Scholes-Merton differential equation. Estimating volatility, Options on stock indices, currencies and futures. Greek Letters and hedging, Value at risk

Recommended Books

1. Douglas K. (2010): Stochastic financial models, Chapman & Hall.
2. John Hull L: Options, futures and other derivatives(Prentice Hall)
3. M.Baxter and A.Rennie L: Financial Calculus(Cambridge, 1996)
4. N.Bingham and R.Keisel : Risk-Nuetral Valuation(Springer)

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).
2. Applied Statistical Genetics with R: For Population-based Association Studies (Use R!) by Andrea S. Foulkes (2009).
3. Handbook of Statistical Genetics (2 volume set) by David J. Balding, Martin Bishop and Chris Cannings (2007)
4. Mathematical and Statistical Methods for Genetic Analysis by Kenneth Lange (2002).
5. Statistical Genetics: Gene Mapping Through Linkage and Association by Benjamin M. Neale, Manuel A.R. Ferreira, Sarah E. Medland and Danielle Posthuma (2008)
6. Statistical Methods in Bioinformatics: An Introduction (Statistics for Biology and Health) by Warren J. Ewens and Gregory R. Grant (2010)
7. The Fundamentals of Modern Statistical Genetics (Statistics for Biology and Health) by Nan M. Laird and Christoph Lange (2010)

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

Review of the General Linear Model for Normal Data: Linear regression, fixed- and mixed-model ANOVA, Analysis of covariance. Extending the General Linear Model: Non-normal error structure, The exponential class, Linear and non-linear link functions. Theory of Estimation and Model Fitting: Likelihood functions and maximum likelihood, Iteratively reweighted least squares. Theory of Statistical Inference: The deviance function, Analysis of deviance, Likelihood ratio tests, Wald tests, Confidence regions. Examples and Illustrations: Classical normal-based models, Logistic and other binary regression, Log-linear models for count data, Gamma regression models. Extending Generalized Linear Models: Extending the exponential class, Over-dispersed models, Quasi-likelihood models, generalized estimating equations, Polytomous response models.

Recommended Books

1. An Introduction to Generalized Linear Models, Second Edition, A.J. Dobson (1990) Chapman & Hall.
2. Applying Generalized Linear Models, James Lindsey, Springer-Verlag, 1997.
3. Bayesian Data Analysis, (1995) A. Gelman, J. Carlin, H. Stern, D. Rubin, Chapman & Hall.
4. Crawley, M. J. (1993). *GLIM for Ecologists*. Blackwell Scientific Publications, Oxford.

5. Dobson, A. J. (2001). *An Introduction to Generalized Linear Models*, Second Edition. Chapman and Hall/CRC, London.
6. *Generalized Linear Models*, Second Edition (1989) Peter McCullagh and John A Nelder, Chapman and Hall.
7. Hardin, J., and Hilbe, J. (2001). *Generalized Linear Models and Extensions*. Stata Press, College Station, Texas.
8. *Markov Chain Monte Carlo in Practice* (1996), W.R. Gilks, S. Richardson, D.J. Spiegelhalter, Chapman & Hall.
9. McCulloch, C., and Searle, S. (2001). *Generalized, linear and mixed models*. Wiley, New York.
10. *Modelling Frequency and Count Data*, J. K. Lindsey (1995) Oxford University Press.
11. *Multivariate Statistical Modelling Based on Generalized Linear Models*, (1994) Tutz, L. Fahrmeir and G. Tutz, Springer Series in Statistics, New York.
12. *Nonparametric Regression and Generalized Linear Models: A roughness penalty approach* (1994). Peter J. Green, Bernard W Silverman, Chapman & Hall.
13. *Statistical Models in S*, John M Chambers, Trevor J Hastie. (1992) Chapman & Hall.

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:

1. Crowder M.J. and Hand D.J. (1999): *Analysis of Repeated Measures*, Chapman and Hall.
2. Montgomery, D.C. (2001). *“Design and Analysis of Experiment”*, John Wiley and Sons. New York
3. Stevens, J. (1996). *“Applied multivariate statistics for the social sciences”*, 3rd ed. Lawrence Erlbaum Associates, New Jersey, P: 450-518
4. Weinfurt, K.P. (1995). *“Repeated Measure Analysis”*, In L.G. Grimm

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:

1. Andrew, R. W. Statistical Pattern Recognition. Second edition. John Willey & Sons Ltd. UK, (2002).
2. Bramer, M. Principles of Data Mining. Springer-Verlag London Limited UK, (2007).
3. Breiman, L., Friedman, J. H., Olshen, R. A. & Stone, C. J. Classification and Regression Trees. Wadsworth International Group, Belmont, CA, (1984).
4. Efron, B. & Tibshirani, R. J. An Introduction to the Bootstrap. Chapman and Hall, London, UK, 1993.
5. Rao, C. R., Wegman, E. J. & Solka, J. L. Handbook of Statistics, Vol. 24: Data mining and data visualization. Elsevier B.V., North Holland, 2005.
6. Ripley, B. D. Pattern Recognition and Neural Networks. Cambridge, New York, NY, 1996.
7. Tan, P., Steinbach, M. & Kumar, V. Introduction to Data Mining. Addison Wesley, New York, 2006.

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:

1. Brady T. West, Kathleen B, Welch and Andrzej T. Galecki. 2007. Linear Mixed Models: A Practical Guide Using Statistical Software. Chapman and Hall.
2. Charles E. McCulloch and Shayle R. Searle. (2001). Generalized, Linear, and Mixed Models, Willey Series in Probability and Statistics. Willey and Sons, New York.
3. Demidenko, E. (2004). Mixed Models—Theory and Applications. Willey and Sons, New York.
4. Jiang, J. (2007). Linear and Generalized Linear Mixed Models and Their Applications: Springer Series in Statistics, Springer.
5. Linear Mixed-Effects Modeling in SPSS: An Introduction to the Mixed Procedure, SPSS Technical Report LMEMWP-1002, Chicago, IL, 2002.
6. Littell, R.C., Milliken, G.A., Stroup, W.W., and Wolfinger, R.D., SAS System for Mixed Models, SAS Publishing, Cary, NC, 1996.

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

Stochastic Process: Introduction, independent process, independent processes: Discrete Parameter and continuous parameter, Markov Process, Markov Chains, Discrete Parameter, Markov Chains: Discrete Parameter, Continuous parameter, Renewal theory.

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 queuing 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:

1. Brownsor, R. (1983). Operation Research – Schaum’s outline Series – McGraw Hill.
2. Daniel P. Hayman, Daniel P. Hayman Mathew J. Sobel (2003), Stochastic Models in Operations Research, vol.1 & 2, Dover Publication.
3. Frederick S. Hillier and Gerald J. Lieberman, (2006). Introduction to Operations Research. McGraw Hill Higher Education.
4. Gupta P.K & Hira D.S (1994) Operations Research S. Chand & Co. New Delhi.
5. Hiller F.S and Lieberman, GJ (1992). Introduction to Operation Research Holden Day.
6. J. Mehdi, Stochastic Process, (1985) Wiley Eastern Limited New Delhi.
7. Paul A. Jensen (2004), Operations Research Model and Method.
8. Richard Bronson (1997) Operation Research, Schaum’s Outline Series McGraw Hill international Book Company Singapore.
9. S. French, R. Hartley, L. C Thomas and D.J White (1986) Operation Research Techniques.
10. Sheldon M. Ross, (2004) “Stochastic Processes” John Wiley & sons, Inc.
11. Taha, H.A (1998). Operation Research, Macmillan, London.

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:

1. Anthony S. Bryk and Stephe W.Raudenbus (2002). Hierarchical Linear models: Applications and Data analysis Methods 2nd Edition size publication.
2. Goldstein, H. (2010). Multilevel Statistical Models, 4th edition, Willey & Sons.

3. Goldstein, H. (1995). *multilevel statistical models*. (2nd ed). New York: John Wiley.
4. Hox, J. J. (2010). *Multilevel Analysis: Techniques and Applications*, Second Edition, Routledge Publisher.
5. Kreft, I., and De Leeuw, J. (1998). *Introducing multilevel modeling* thousand oaks, CA: sage.
6. Snijders, I., and Bosker, R. (1999). *Multilevel analysis*. London: sage.

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:

1. Barnett, V. (2005). *Environmental Statistics: Methods and Applications*. John Wiley and Sons.
2. Bryan F.J. Manly (2009). *Statistics for Environmental Science and Management*, 2nd Ed., Taylor and Francis.
3. Wayne R. Ott (1994). *Environmental Statistics and Data Analysis*, Amazon

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

Concepts and definition of quality, Statistical Process Control (SPC) tools, Multivariate Process Control, Hotelling's T^2 control chart, Failure-Mode and Effect Analysis (FMEA), Quality Function Deployment (QFD) - Akao model, House of Quality. Design of experiments, Fractional factorial designs, Robust designs. Taguchi experiments in industrial setups, Mixture Designs. Six Sigma concept, Define, measure, improve, control (DMAIC) philosophy. Design for Six Sigma (DFSS), Quality standards - ISO 9000, ISO-14000, ISO 22000

Recommended Books:

1. Banks, J. (1989). *"Principles of Quality Control"*. John Wiley, New York.
2. Feigenbaum, A.V. (1986). *"Total Quality Control"*. McGraw Hill, New York.

3. Juran, J.M. and Guyana, F.K. (1988). "*Juan's Quality Control Handbook*". McGraw-Hill New York.
4. Miltag H. J. and Rinne H. (1993). "*Statistical Methods of Quality Assurance*", Chapman & Hall, London.
5. Montgomery, D.C. (2013). "*Introduction to Statistical Quality Control*". McGraw Hill, New York.
6. Nelson, W. (1990). "*Accelerated Testing*". John Wiley, New York.
7. Ryan, T.P. (1989). "*Statistical Methods for Quality Improvement*". John Wiley, New York.
