

CURRICULUM
OF
STATISTICS
BS (HONS)
MS (HONS)

(Revised 2006)



HIGHER EDUCATION COMMISSION
ISLAMABAD

CURRICULUM DIVISION, HEC

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Miss Ghayyur Fatima	Deputy Director (Curri)
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PREFACE

Curriculum of a subject is said to be the throbbing pulse of a nation. By looking at the curriculum one can judge the state of intellectual development and the state of progress of the nation. The world has turned into a global village; new ideas and information are pouring in like a stream. It is, therefore, imperative to update our curricula regularly by introducing the recent developments in the relevant fields of knowledge.

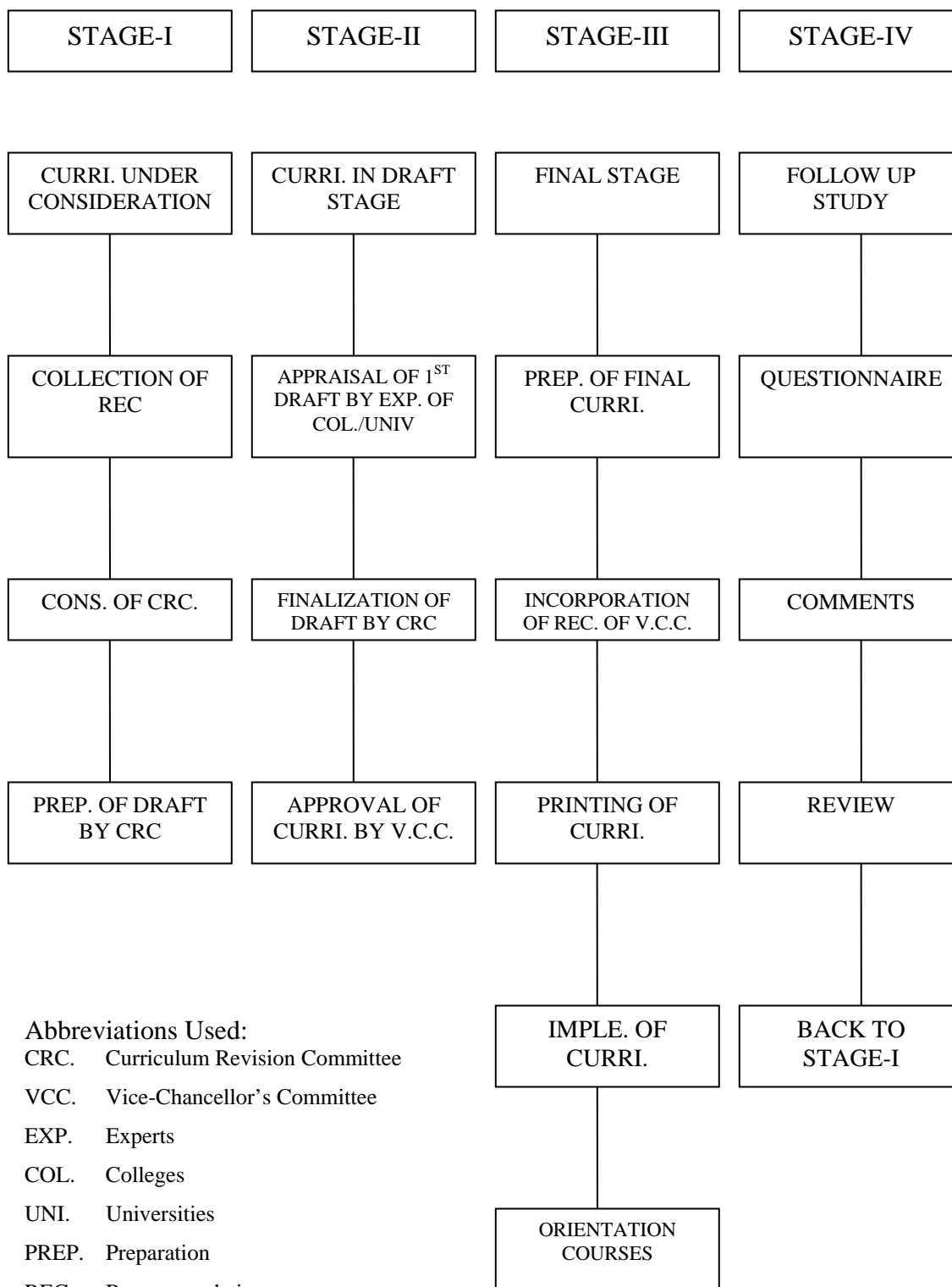
In exercise of the powers conferred by sub-section (1) of section 3 of the Federal Supervision of Curricula Textbooks and Maintenance of Standards of Education Act 1976, the Federal Government vide notification no. D773/76-JEA (Cur.), dated December 4, 1976, appointed University Grants Commission as the competent authority to look after the curriculum revision work beyond class XII at bachelor level and onwards to all degrees, certificates and diplomas awarded by degree colleges, universities and other institutions of higher education.

In pursuance of the above decisions and directives, the Higher Education Commission (HEC) is continually performing curriculum revision in collaboration with universities. According to the decision of the special meeting of Vice-Chancellors' Committee, curriculum of a subject must be reviewed after every 3 years. For the purpose, various committees are constituted at the national level comprising senior teachers nominated by universities. Teachers from local degree colleges and experts from user organizations, where required, are also included in these committees. The National Curriculum Revision Committee for Statistics in its meeting held in March 27-29, 2006 at the HEC Regional Centre, Karachi revised the curriculum after due consideration of the comments and suggestions received from universities and colleges where the subject under consideration is taught. The final draft prepared by the National Curriculum Revision Committee duly approved by the Competent Authority is being circulated for implementation by architectural institutions.

Prof. Dr. Syed Altaf Hussain
Member (Acad/R&D)

August 2006

CURRICULUM DEVELOPMENT



INTRODUCTION

The Final National Curriculum Revision Committee meeting in Statistics was held from March 27-29, 2006, at HEC Regional Centre, Karachi to prepare the draft curriculum of Statistics for BS (Hons.) 4 year Programme and two years MS (Hons.). The following attended:

1. Prof. Dr. G.R. Pasha, Convener
Chairman & Dean Sciences & Agri,
Bhauddin Zakriya University,
Multan
2. Prof. Dr. Muhammad Inayat Khan, Member
Department of Mathematics and Statistics,
University of Agriculture,
Faisalabad.
3. Prof. Dr. Munir Akhtar, Member
Chairman,
Department of Statistics,
Islamia University, Bahawalpur,
4. Prof. Zahid Mahmood, Member
Ex Chairman,
Department of Statistics,
University of Karachi,
Karachi.
5. Prof. Asim Jamal Siddiqui, Member
Chairman,
Department of Statistics,
University of Karachi,
Karachi.
6. Mr. Jamshaid Iqbal, Member
Asstt. Professor,
Department of Statistics,
Quaid-i-Azam University,
Islamabad.
7. *Dr. Abdul Khalique, Member
Professor,
National University of Computer &
Emerging Sciences (FAST),
Lahore

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| 8. | Mr. S. Sajjad Hussain Bokhari,
Chairman,
Department of Statistics,
Gomal University, D.I.Khan | Member |
| 9. | Dr. Mujahid Rasool,
Professor,
Department of Statistics
FC College University, Lahore | Member |
| 10. | *Dr. Ghazala Sadiq,
Professor/Head of Deptt. Basic Sciences,
Institute of Space Technology,
P.O. Box 2750, Islamabad 44000 | Member |
| 11. | Dr. Tajuddin Islamuddin,
HEC Foreign Professor,
Institute of Business Administration,
Karachi | Member |
| 12. | Prof. Dr. Salahuddin,
Department of Statistics,
University of Peshawar,
Peshawar. | Member |
| 13. | Mr. Allah Bux Chhutto,
Associate Professor,
Department of Statistics,
Sindh Agriculture University, Tandojam. | Member |
| 14. | Ch. Muhammad Azam,
Assistant Professor,
Department of Statistics & Mathematics,
University of Arid Agriculture,
Murree Road, Rawalpindi. | Member |
| 15. | Mr. Faisal Maqbool Zahid,
Lecturer,
GC University, Faisalabad. | Member |
| 16. | Mr. Sohail Akhtar,
Lecturer,
University of Malakand,
Chakdara, NWFP | Member |
| 17. | Ms. Hina Muzaffar,
Lecturer,
GC University, Lahore | Member |

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| 18. | Mr. Abdul Hakeem Makhdoom,
Dy. Director General,
Federal Bureau of Statistics, Islamabad | Member |
| 19. | *Dr. Munir Ahmed
Rector & Professor of Statistics,
National College of Business and Economics,
Lahore | Member |
| 20. | Ms. Ayesha Roohi,
Associate Professor,
Lahore College for Women University,
Jail Road, Lahore. | Secretary / Member |

(*These members were not present in the final meeting due to their pre occupation.)

The meeting started with the recitation of Holy Quran by Mr. S. Sajjad Shah, Chairman, Department of Statistics, Gomal University, D.I. Khan. Prof. S. M. Iqbal, Director, HEC Karachi, welcomed the participants and praised their efforts in the preparation of the first draft.

As Dr. Munir Ahmad, convener in the first NCRC meeting was unable to come, the co-convener Dr. G R. Pasha, Chairman, Department of Statistics, BZU was asked to chair the meeting. Dr. Aysha Roohi continued as secretary. Dr. G. R. pasha thanked the participants for reposing the confidence in him.

It was decided that the BS Hons. (4 - year) programme would be finalized first, keeping in view the comments and suggestions of the experts on the first draft.

It was again stressed that BS (4-year) should be an integrated programme and students joining this programme in the 3rd year should be offered deficiency courses. Duration of the semester was fixed at 18 weeks, including examinations period. Course codes were also finalized.

Mr. Abdul Hakeem Makhdoom from FBS was of the view that official statistics should be a compulsory course, so that statisticians joining statistical organizations do not merely possess theoretical knowledge but must be familiar with the working of the organization as well.

The BS (4-year) programme has been formulated such that graduating students are not only able to compete with others in the job market but are also capable enough to provide consultancy services when required to do so.

The MS (2-year) programme equips the students to pursue higher education, within the country and overseas, apart from capabilities acquired in the bachelor's programme. The final draft of the MS (2 year) programme was also approved. This programme will be of 36 cr.hrs. of which 12 cr.hrs will be for thesis. The list of courses to be taught at MS level was finalized and it was left to the universities to decide which courses should be taught, keeping in mind the availability of the faculty in that area/subject.

Dr. Altaf Ali G. Shaikh, Adviser (Acad/R&D), HEC Islamabad addressed the committee on the final day and commented that the HEC requires BS (4-years) programme should have courses on communication and IT skills and report writing.

Dr. G.R. Pasha thanked Dr. Altaf Ali G. Shaikh and told him that the final draft prepared by the NCRC was in line with the requirements of the HEC.

BS (Hons.) 4 years program in Statistics at University Level

Aims and Objectives

This attempt to shift from the current two years degree programme to four year BS (Hons.) programme is to make it equivalent to the internationally recognized sixteen years of schooling for a graduate followed by a two year education for a master degree in Statistics.

The aims and objectives of the programme are:

1. To equip the graduates with the knowledge of statistical theory, statistical software and techniques of data collection and analysis so that they can compete in the job market and contribute towards the economic development of Pakistan.
2. To provide a sound footing of the subject matter of statistical theory so that they can pursue higher degrees and research in the field of Statistics.

BS (4 years) Programme in Statistics

BS Statistics programme will contain a total of 135 credit hours. The detail is as under:

<u>Statistics Courses</u>	<u>Credit Hours</u>
STAT-101 Introductory Statistics	3
STAT-102 Introduction to Probability Distributions	3
STAT-201 Basic Statistical Inference	3
STAT-202 Introduction to Regression Analysis and Experimental Design	3
STAT-203 Applied Statistics	3
STAT-204 Statistical Packages	3
STAT-301 Probability & Probability Distributions-I	3
STAT-302 Probability & Probability Distributions-II	3
STAT-303 Sampling Techniques-I	3
STAT-304 Sampling Techniques-II	3
STAT-305 Design and Analysis of Experiments-I	3
STAT-306 Design and Analysis of Experiments-II	3
STAT-307 Regression Analysis	3
STAT-308 Econometrics	3
STAT-309 Statistical Quality Control or	
STAT-310 Non-Parametric Methods	3
STAT-311 Population Studies	3
STAT-401 Statistical Inference-I	3
STAT-402 Statistical Inference-II	3
STAT-403 Applied Multivariate Analysis	3
Optional Courses of Statistics	<u>15</u>
	72

Note: 2 courses of semester-VII and three courses of semester-VIII will be chosen from the list of optional courses of 15 credit hours. Further more there will be a project of 6 credit hours in semester-VIII.

<u>Allied / Supporting Courses</u>	<u>Credit Hours</u>
Calculus-I	3
Calculus-II	3
Calculus-III	3
Computer Programming	3
Numerical Computing/Numerical Methods	3
Economics/Sociology/Psychology/other subjects/Minors	11
Linear Algebra	3

Differential Equations	3
Survey and Research Methods / Internship	<u>3</u>
	35

Compulsory Courses

Credit Hours

English	9
Islamiat	2
Pakistan Studies	2
Communication Skills	6
Fundamentals of Computers	3
Project	<u>6</u>
	28

BS (4 years) Programme in Statistics
Scheme of Studies

<u>1st Year</u>		<u>3rd Year</u>	
Semester-I	Cr.h	Semester-V	Cr.h
English	3	Probability & Probability Distributions-I	3
Fundamentals of Computers	3	Sampling Techniques-I	3
Introductory Statistics	3	Regression Analysis	3
Calculus-I	3	Design & Analysis of Experiments-I	3
Minor I	3	Statistical Quality Control or	3
Islamiat	2	Non- Parametric Methods	
Minor II	2		
Semester-II	Cr.h	Semester-VI	Cr.h
Introduction to Probability Distributions	3	Probability & Probability Distributions-II	3
Calculus-II	3	Sampling Techniques-II	3
Communication Skills - I	3	Econometrics	3
Minor I	3	Design & Analysis of Experiments-II	3
Pakistan Studies	2	Population Studies	3
English (Compulsory)	3		
<u>2nd Year</u>		<u>4th Year</u>	
Semester-III	Cr.h	Semester-VII	Cr.h
Basic Statistical Inference	3	Statistical Inference-I	3
Calculus-III	3	Applied Multivariate Analysis	3
Computer Programming	3	Survey and Research Methods/Internship	3
English (Compulsory)	3	Two courses to be chosen from	
Numerical Computing/Numerical Methods	3	the list of optionals	6
Minor II	3		
Semester-IV	Cr.h	Semester-VIII	Cr.h
Introduction to Regression Analysis & Experimental Design	3	Statistical Inference-II	3
Applied Statistics	3	Project	6
Statistical Packages	3	Three courses to be chosen	9
Linear Algebra	3	from the list of optionals	
Differential Equations	3		
Communication Skills / Report Writing	3		

SUMMARY TABLE

1st Semester	19 Cr. Hrs	2nd Semester	17 Cr. Hrs.
3rd Semester	18 Cr. Hrs.	4th Semester	18 Cr. Hrs.
5th Semester	15 Cr. Hrs.	6th Semester	15 Cr. Hrs.
7th Semester	15 Cr. Hrs.	8th Semester	18 Cr. Hrs.

Total Credit Hours: 135 Cr. Hrs.

Note: From 5th semester onward in all the courses of statistics will also have practicals

DETAILS OF THE COURSES

The proposed outlines of the BS Hons.(4 years) programme in Statistics are as follows:

STAT-101 Introductory Statistics

The nature and scope of the Statistics. Organizing of Data, classification of data, Graphs and Charts: Stem-and leaf diagram, Box and Whisker plots and their interpretation. Measures of Central Tendency and Dispersion: Their properties, usage, limitations and comparison. Calculations for the ungrouped and grouped data. Measures of Skewness and Kurtosis and Distribution shapes.

Probability Concepts, Addition and Multiplication rules, Bivariate frequency tables, joint and marginal probabilities, Conditional probability and independence, Bayes' rule.

Pre-Requisite: Nil

Books Recommended

1. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "*Probability and Statistics*", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
2. Clark, G.M and Cooke, D. (1998), "*A Basic Course in Statistics*" 4th ed, Arnold, London.
3. Walpole, R.E., Myers, R.H and Myers, S.L. (1998), "*Probability and Statistics for Engineers and Scientist*" 6th edition, Prentice Hall, NY.
4. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "*Statistics for Business & Economics*" 9th ed. Prentice Hall, New Jersey.
5. Weiss, N.A.(1997), "*Introductory Statistics*" 4th ed. Addison-Wesley Pub. Company, Inc.
6. Chaudhry, S.M.and Kamal, S. (1996), "*Introduction to Statistical Theory*" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.

STAT-102 Introduction to Probability Distributions

Discrete Random Variables, 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, Normal approximation to Binomial and Poisson distributions.

Pre-requisite: STAT-101

Books Recommended

1. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "*Probability and Statistics*", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
2. Clark, G.M. and Cooke, D. (1998), "*A Basic Course in Statistics*" 4th ed, Arnold, London.
3. Walpole, R.E., Myers, R.H and Myers, S.L. (1998), "*Probability and Statistics for Engineers and Scientist*" 6th edition, Prentice Hall, NY.
4. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "*Statistics for Business & Economics*" 9th ed. Prentice Hall, New Jersey.
5. Weiss, N.A.(1997), "*Introductory Statistics*" 4th ed. Addison-Wesley Pub. Company, Inc.
6. Chaudhry, S.M.and Kamal, S. (1996), "*Introduction to Statistical Theory*" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.

STAT-201 Basic Statistical Inference

Distribution of sample mean and 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.

Chi-Square Procedure. Chi-Square Goodness-of fit Test. Chi-Square Independence Tests.

Pre-Requisite- STAT-102

Books Recommended

1. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "*Probability and Statistics*", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
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. Walpole, R.E., Myers, R.H. and Myers, S.L. (1998), "*Probability and Statistics for Engineers and Scientist*" 6th edition, Prentice Hall, NY.
5. Weiss, N.A. (1997), "*Introductory Statistics*" 4th ed. Addison-Wesley Pub. Company, Inc.
6. Chaudhry, S.M. and Kamal, S. (1996), "*Introduction to Statistical Theory*" Part I, II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.

STAT-202 Introduction to Regression Analysis and Experimental Design

Concepts of Regression and Correlation, Simple 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). Introduction to Non-Parametric Statistical Methods,

Pre-Requisite: STAT-101

Books Recommended

1. Clark, G. M. and Kempson, R. E. (1997), "*Introduction to the Design & Analysis of Experiment*" Arnold London.
2. Walpole, P.E., Myers R.H., Myers S.L. (1998), "*Probability and Statistics for Engineers and Scientists*", 7th ed. Prentice Hall.
3. Weiss, N.A. (1997), "*Introductory Statistics*" 4th ed. Addison-Wesley Pub. Company, Inc.
4. Chaudhry, S.M., and Kamal, S., (1996), "*Introduction to Statistical Theory*" Part I, II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.

STAT-203 Applied Statistics

Sampling: Need of sampling, Sample versus population, Random and non-random sampling, concepts of statistic and population parameter. Sampling techniques: Simple Random, Stratified and Systematic random sampling. Census and survey problem, raming 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 (Laspayers, Paaches and Fishers ideal index numbers). Consumer price index (CPI) and Sensitive Price Indicators.

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

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

Pre-Requisite: STAT-101

Books Recommended

1. Clark, G.M. and Cooke, D. (1998), "*A Basic Course in Statistics*" 4th ed, Arnold, London.
2. Mclave, J.T. Benson, P.G. and Snitch, T. (2005) "*Statistics for Business & Economics*" 9th Prentice Hall New Jersey.
3. Walpole, P.E. Myers, R.H., Myers S.L. (1998), "*Probability and Statistics for Engineers and Scientists*", Prentice Hall.
4. Chaudhry, S.M. and S. Kamal, (1996), "*Introduction to Statistical Theory*" Part I, II, 6th Ed, Ilmi Kitab Khana, Lahore, Pakistan.
5. Cochran, W.G. "*Sampling Techniques*".3rd Ed.
6. Pollard, A.H.. Yousuf, F. and Pollard G.M. (1982), "*Demographic Techniques*", Pergamon Press, Sydney.

STAT-204 Statistical Packages

Introduction to Minitab, data manipulation in Minitab, graphical representation in Minitab, Qualitatively 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. (Use of SPSS, Minitab, Matlab, Statistica is based upon the availability of Software)

Pre-Requisite: STAT-201

Books Recommended

1. Ryan, Barbara F.; Joiner, Brian L. and Cryer, Jonathan D.(2005) MINITAB Handbook, 5th Edition, Duxbury Press, California.
2. Delwiche, Lora D. and Slaughter Susan J. (1998) [The Little SAS Book : A Primer, Second Edition](#), SAS institute, North Carolina.
3. Norusis, Marija(2006) SPSS 14.0 Guide to Data Analysis, Prentice Hall, New Jersey.
4. SPSS (2006) SPSS 14.0 Base User's Guide, , Prentice Hall, New Jersey.
5. [Marques de Sá](#), Joaquim P.(2003) Applied **Statistics using SPSS**, STATISTICA and MATLAB

STAT-301 Probability and Probability Distributions-I

Probability as a set function. Conditional probability and Bayes' theorem. Random variables, 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. 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 cumulants. Probability distributions: Hypergeometric, Binomial, Multinomial, Negative Binomial, Geometric, Poisson, Normal and Lognormal distributions with moments and commulants.

Pre-Requisite: STAT-102

Books Recommended

1. Stirzaker, D. (1999). "*Probability and Random Variables*". Cambridge University Press, Cambridge.
2. Stuart, A. and Ord, J .K. *Kendall's*' (1998), "*Advanced Theory of Statistics*", Vol. I, Charles Griffin, London.
3. Hirai, A.S. (1998), "*A Course in Mathematical Statistics*", Ilmi Kutab Khana, Lahore.
4. Fridett, B. & Gray, L. (1997). "*A Modern Approach to Probability Theory*" Birkhallser, Boston.
5. Freund, J. E. (1997). "*Mathematical Statistics*", Prentice Hall, New Jersey 6th edition.
6. Mood, A.M, Graybill, F.A. and Boss, D.C. (1997), "*Introduction to the Theory of Statistics*", McGraw Hill, New York.
7. Khan, M. K., (1996). "*Probability with Applications*", Maktiba Ilmi, Lahore.
8. Hogg, R.M. and Craig, A.T. (1995), "*Introduction to Mathematical Statistics*". Prentice Hall, Engle wood Cliffs, New Jersey.
9. Haq, M. (1984). *Foundation of Probability and Statistics*, Tahir sons, Urdu Bazar, Karachi.

STAT-303 Sampling Techniques-I

Basic concepts, advantages of sampling methods, requirements of a good sample, bias, sampling and non-sampling errors. Steps and problems involved in planning and conduct of census and 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.

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

Pre-Requisite: STAT-203

Books Recommended

1. Raj, D. & Chandhok, P. (1998), "*Sample Survey Theory*". Narosa Publishing House, New Delhi.
2. Ferguson, T.S. (1996), "*A Course in large Sample Theory*", Chapman & Hall, London.

3. Singh, R. and Singh N, (1996), "*Elements of Survey Sampling*", Kulwar Academic Publisher, Dodrecht.
4. Kish, L. (1992). "*Survey Sampling*", John Wiley, New York.
5. Sukhatme, P.V, Sukhatme, B., Sukhatme, S., and Asok, A. (1985), "*Sampling Theory of Survey with Application*". Iowa State University Press.
6. Cochran, W.G. (1977), "*Sampling Techniques*", 3rd ed, John Wiley and Sons, New York.
7. Raj, D. (1971) "*Design of Sample Survey*". McGraw Hill, New York.

STAT-307 Regression Analysis

General linear model and its assumptions, Least squares estimators, MLE, Least squares estimators, tests of hypothesis, tests of significance of a single and complete regression, tests of significance of subset of coefficients. Significance tests and confidence intervals. 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

Books Recommended

1. Draper, N.R. and Smith, H. (2004). "*Applied Regression Analysis*", John Wiley. New York.
2. Baltagi, B. H. (1999). "*Econometrics*", 2nd Edition, Springer Varlog.
3. Gujarati, D. (1998). "*Econometrics*", John Wiley, New York.
4. Wonnacott, T.H. and Wonnacott R.J. (1998). "*Econometrics*", John Wiley, New -York.
5. Johnston, J. and Di. Nardo, J., (1997). "*Econometric Method*", 4th Edition, McGraw Hill, New York.
6. Ryan, P. T. (1996) "*Modern Regression Methods*", John Wiley and sons Inc. New York.
7. Montgomery, D.C., and Peck E.A. (1992). "*Introduction to linear Regression Analysis*", 2nd Edition, John Wiley and sons Inc. New York.
8. Guttman, I, (1980); "*Linear Models: An Introduction*", John Wiley, New York.
9. Koutsoyiannis, A. (1980), "*Theory of Econometrics*", Macmillan. N.Y.
10. Maddala, G.S. (1977). "*Econometrics*", McGraw Hill. New York.
11. Searle, S. R. (1971), "*Linear Models*", 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. Effect of violation of assumptions and transformations.

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.

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

Pre-Requisite: STAT-202

Books Recommended

1. Montgomery, D.C. (2000). *“Design and Analysis of Experiments”*, John Wiley, New York.
2. Clarke, G.M., and Kempton, R.E. (1997), *“Introduction to the Design & Analysis of Experiments”*, Edward Arnold.
3. 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.
4. Boniface, D.R. (1995). *“Experiment Design & Statistical Methods”*, Chapman & Hall.
5. Myers, R.H. and Montgomery, D.C. (1995). *“Response Surface Methodology; Process & Product Optimization Using Design”*, John Wiley.
6. Clarke, G.M. (1994). *“Statistics & Experimental Design”*. Edward Arnold.
7. Harold, R. L (1992). *“Analysis of Variance in Experimental Design”*. Springer Verlag:
8. Maxwell, S.E. and Delaney, H.D. (1990). *“Designing Experiments and Analysis of Data”*. A model comparison perspective. Belmont and Wadson.
9. Mead, R. (1988). *“The Design of Experiments”*. Cambridge University Press, Cambridge.
10. Das, M.N.and Geri, N.C, (1986). *“Design and Analysis of Experiments”*, John Wiley, New York.
11. Gomez, K.A., and Gomez, A.A. (1984).*“Statistical Procedures for Agricultural Research”*, 2nd Edition, John Wiley, New York.
12. Hicks, C.R. (1982). *“Fundamental Concepts in Design and Analysis of Experiments”* Saunders
13. Cochran, W.G. and Cox, G.M. (1957). *“Experimental Design”*, John Wiley, New York.

STAT-309 Statistical Quality Control

Concept of quality control, total control and 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 X, R and S-charts.

Process capability analysis: Designed experiments. Process improvements using design of experiments. Taguchi Method. Orthogonal fractional factorial designs.

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

Books Recommended

1. Montgomery, D.C. (2004). *“Introduction to Statistical Quality Control”*. McGraw Hill, New York.
2. Miltag H. J. and Rinne H. (1993). *“Statistical Methods of Quality Assurance”*, Chapman & Hall, London.
3. Nelson, W. (1990). *“Accelerated Testing”*. John Wiley, New York.
4. Banks, J. (1989). *“Principles of Quality Control”*. John Wiley, New York.
5. Ryan, T.P. (1989). *“Statistical Methods for Quality Improvement”*. John Wiley, New York.
6. Juran, J.M. and Guyana, F.K. (1988). *“Juan’s Quality Control Handbook”*. McGraw Hill New York.
7. Feigenbaum, A.V. (1986). *“Total Quality Control”*. McGraw Hill, New York.

STAT-310 Non-Parametric Methods

Location estimates for single samples: 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 – Turkey 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-202,301

Books Recommended

1. Conover, W.J. (1999), *Practical Nonparametric Statistics*, 3rd Edition, John Wiley and Sons, New York.
2. Maritz, J.S. (1995). *Distribution-Free Statistical Methods*. Chapman & Hall London.
3. Gibbons, J.D. and Chakraborti, S.(1992), *Nonparametric Statistical Inference*, Marcel Decker, New York.
4. Sprint, P. (1989). *Applied Nonparametric Statistical Methods*. Chapman & Hall London.
5. Lehman, E.L. (1973), *Nonparametric Statistical Methods, based on Ranks*, Holden-Day San Francisco.

STAT-302 Probability and Probability Distributions-II

Probability Distributions: Uniform, Exponential, Gamma, Laplace, Rayleigh with moments and cumulates 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 and their applications. Order statistics. Distributions of rth and sth order statistics. Bivariate Normal distribution.

Pre-Requisite: STAT-301

Books Recommended

1. Stirzaker, D. (1999). "*Probability and Random Variables*". Cambridge University Press, Cambridge.
2. Stuart, A. and Ord, J .K. *Kendall's* (1998), "*Advanced Theory of Statistics*", Vol. I, Charles Griffin, London.
3. Hirai, A.S. (1998), "*A Course in Mathematical Statistics*", Ilmi Kutab Khana, Lahore.
4. Fridett, B. & Gray, L. (1997). "*A Modern Approach to Probability Theory*" Birkhallser, Boston.
5. Freund, J. E. (1997). "*Mathematical Statistics*", Prentice Hall, New Jersey.
6. Mood, A.M, Graybill, F.A. and Boss, D.C. (1997), "*Introduction to the Theory of Statistics*", McGraw Hill, New York.

7. Hogg, R.M. and Craig, A.T. (1995), "*Introduction to Mathematical Statistics*". Prentice Hall, Engle wood Cliffs, New Jersey.
8. Khan, M. K., (1996). "*Probability with Applications*", Maktiba Ilmi, Lahore.
9. Haq, M. (1984). "*Foundation of Probability and Statistics*", Tahir sons, Urdu Bazar, Karachi.

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. Sampling and non sampling errors and their sources. non-response, their sources and bias. Randomized response. Critical study of National sample surveys conducted in Pakistan: Census of Agriculture, Household Income and Expenditure Survey (HIES), Pakistan Demographic Survey (PDS) and National Population and Housing Census and Surveys (NPHCS).

Pre-Requisite: STAT-303

Books Recommended

1. Des Raj & Chandhok, P. (1998), "*Sample Survey Theory*". Narosa Publishing House, New Delhi.
2. Ferguson, T.S. (1996), "*A Course in Large Sample Theory*", Chapman & Hall, London.
3. Singh, R. and Singh N, (1996), "*Elements of Survey Sampling*", Kulwar, Dodrecht.
4. Kish, L. (1992), "*Survey Sampling*", John Wiley, New York.
5. Sukhatme, P.V, Sukhatme, B., Sukhatme, S., and Asok, A. (1985), "*Sampling Theory of Survey with Application*". Iowa State University Press.
6. Cochran, W.G. (1977), "*Sampling Techniques*", John Wiley and Sons, 3rd ed, New York.
7. Des Raj, (1971), *Design of Sample Survey*. McGraw Hill, New York.
8. Various publications of FBS, ACO and PCO.

STAT-308 Econometrics

Errors in Variables. Problems of autocorrelation, multicollinearity, heteroscedasticity and their solution. Ridge regression. Lagged variables. Dummy 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

Books Recommended

1. Draper, N.R. and Smith, H. (2004). "*Applied Regression Analysis*", John Wiley, New York.
2. Baltagi, B. H. (1999). "*Econometrics*", 2nd Edition, Springer Varlog.
3. Gujrati, D. (1998). "*Econometrics*", John Wiley, New York.
4. Wonnacot, T.H. and Wonnacot R.J. (1998). "*Econometrics*", John Wiley, New York.
5. Johnston, J. and Di. Nardo, J., (1997). "*Econometric Method*", 4th Edition, McGraw Hill, New York.
6. Montgomery, D.C., and Peck E.A. (1992). "*Introduction to Linear Regression Analysis*", 2nd Edition, John Wiley and sons Inc. New York.
7. Guttman, I. (1980); "*Linear Models: An Introduction*", John Wiley, New York.
8. Koutsoyiannis, A. (1980), "*Theory of Econometrics*", Macmillan.
9. Maddala, G.S. (1977). "*Econometrics*", McGraw Hill. New York.
10. Searle, S. R. (1971), "*Linear Models*", 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, Quasi-Latin square designs. Split-plot, split block, split-split plot, strip plot and nested designs. Missing observations in Split plot design.

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

Introduction of response surface methods: First and Second order designs. Central composite designs. Fitting of response surface models and estimation of optimum/maximum response.

Pre-Requisite: STAT-305

Books Recommended

1. Montgomery, D.C. (2000). "*Design and Analysis of Experiments*", John Wiley, New York.
2. Clarke, G.M., and Kempton, R.E. (1997), "*Introduction to the Design & Analysis of Experiments*", Edward Arnold.
3. Steel, G. D., Terrie, and Dickey A. (1997). "*Principles and Procedures of Statistics: A Biometrical Approach*" 3rd Edition, McGraw Hill, New York.
4. Boniface, D.R. (1995). *Experimental Design & Statistical Methods*, Chapman & Hall.
5. Myers, R.H. and Montgomery, D.C. (1995). "*Response Surface Methodology; Process & Product Optimization Using Design*", John Wiley.
6. Clarke, G.M. (1994). "*Statistics & Experimental Design*". Edward Arnold.
7. Harold, R. L (1992). "*Analysis of Variance in Experimental Design*". Springer Verlag:
8. Maxwell, S.E. and Delaney, H.D. (1990). *Designing Experiments and Analysis of Data. A Model Comparison Perspective*. Belmont and Wadson.
9. Mead, R. (1988). "*The Design of Experiments*". Cambridge University Press, Cambridge.
10. Das, M.N.and Giri, N.C, (1986). "*Design and Analysis of Experiments*", John Wiley, New York.
11. Gomez, K.A., and Gomez, A.A. (1984). "*Statistical Procedures for Agricultural Research*", 2nd Edition, John Wiley, New York.
12. Hicks, C.R. (1982). "*Fundamental Concepts in Design and Analysis of Experiments*"; Saunders
13. Cochran, W.G. and Cox, G.M. (1957). "*Experimental Design*", John Wiley, New York.

STAT-311 Population Studies

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. General testing procedures. Testing the accuracy of age and sex data. Fertility and mortality measures. Total and general fertility rates. 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.

Pre-Requisite: STAT-201 & 202

Books Recommended

1. Jay Weinstein, Vijayan, K. Pillai, (2001) "*Demography: The Science of Population*". Allyn & Bacon.
2. Hind, A., (1998). "*Demographic Method*", Arnold
3. United Nations (1998), "*World Population Assessment*", UNFPA; New York.
4. Govt. of Pakistan (1998), "*National, Provincial and District census reports and other supplementary reports with respect to 1998 census*"; PCO, Islamabad.
5. United Nations (1996), "*Added years of Life in Asia*", ESCAP; U.N., Thailand.
6. Palmore, J.A; Gardner, R.W. (1994), "*Measuring Mortality Increase*"; East West Centre, Honolulu.
7. 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.
8. Impagliazo, J. (1993), "*Deterministic Aspects of Mathematical Demography*", Springer Verlag New York.
9. United Nations (1990), "*World Population Monitoring 1989*", UNFPA.
10. Rukanuddin A.R. and Farooqi, M.N.I., (1988), "*The State of Population in Pakistan – 1987*", NIPS, Islamabad.
11. Keyfitz, N. (1983) "*Applied Mathematical Demography*", Springer Verlag N.Y.
12. Pollard, A.H., Yousaf, F & Pollard, G.M. (1982), "*Demographic Techniques*", Pergamon Press, Sydney.
13. Pakistan Demographic Survey, Govt. of Pakistan, Federal Bureau of Statistics.
14. Publications of population census organizations.

STAT-401 Statistical Inference-I

Estimation of Parameters. Properties of Estimators: unbiasedness, consistency, sufficiency, efficiency, 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

Books Recommended

1. Mood, A.M., Graybill, F.A. and Boss, D.C. (1997). *“Introduction to the Theory of Statistics”*. McGraw Hill, New York.
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. Stuart, A. and Ord, J.K. (1998). *Kendall’s’ “Advanced Theory of Statistics” Vol. II*. Charles Griffin, London.
5. Zacks, S. (1973), *“Parametric Statistical Inference”*, John Wiley, New York.
6. Rao, C.R., (1973). *“Linear Statistical Inference and its Applications”*, John Wiley, New York.
7. Bickel, P.J., and Doksum, K.A. (2001), *Mathematical Statistics, Vol I*, Prentice Hall, N.J., 2nd ed.

STAT-403 Applied Multivariate Analysis

Introduction to Multivariate Normal Distribution. Estimation of the mean vector and covariance matrix. Multivariate analysis of variance (MANOVA). Principal components analysis, Factor analysis, Discriminate analysis, Canonical Correlation Cluster analysis. Multidimensional scaling.

Pre-Requisite: STAT-302

Books Recommended

1. Anderson, T.W. (2003). *“An Introduction to Multivariate Statistical Analysis”*, John Wiley, New York.
2. Afifi, A. A. and Clark Virginia (2000). *“Computer Aided Multivariate Analysis”*, Lifetime learning publications, Belmont California.
3. Flurry B. (1997). *“A First Course in Multivariate Statistics”*, Springer Valerg, New York.
4. Manly, B.F.J. (1994). *“Multivariate Statistical Methods, A Primer”* 2nd Edition, Chapman and Hall, London.
5. Johnson, R.A. and Wincher, D.W. (1992). *“Applied Multivariate Statistical Analysis”*. Prentice Hall. London.
6. Morrison, F. (1990). *“Multivariate Statistical Methods”*, McGraw Hill, New York.
7. Chatfield, C. and Collins, A.J. (1980). *“Introduction to Multivariate Analysis”*, Chapman and Hall, London.
8. Mardia, K.V., Kent, J.T. and Bobby, J.M. (1979). *“Multivariate Analysis”*, Academic Press, London.
9. Everett, B.J. (1974). *“Cluster Analysis”*, McGraw Hill, New York.

STAT-404 Survey and Research Methods

Definition of Research, Types of Research, Selection of Problem, Search of References, Formation of Hypothesis and Procedure for its Testing, Research Methodology, Planning of Experiments to Test Hypothesis Objectivity, Principles of Experimental Design, Steps in Experimentation, 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.

PRACTICAL:

Survey of Literature on a Given Topic, Collection of References from Various Sources Including SD-ROM Data Base. Collection of Primary and Secondary Data, Arrangement of Primary and Secondary Data, Preparation of Scientific Report for Publication, if Possible

Pre-Requisite: STAT-304

Books Recommended

1. Andrew, C.O. and P.E. Hildebrand. (1993) "Applied Agricultural Research", Foundations and Methodology, Western Press.
2. Hashmi, N. (1989) "Style Manual of Technical Writings", USAID/NARC, Islamabad.
3. Gimbaled, J. and W.S. Acuter (1988) "MLA handbook for Writers of Research Papers", McGraw The Modern Language Association of America.
4. Little, T.M. and F.J. Hills (1978) "Agricultural Experimentation", John Wiley & Sons.

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

Books Recommended

1. Stuart, A and Ord, J.K. (1998). *Kendall's' "Advanced Theory of Statistics" Vol. II*. Charles Griffin, London.
2. Lindgren, B.W. (1998). *"Statistical Theory"*. Chapman and Hall, New York.
3. Mood, A.M. Gray Bill, F.A. and Boss, D.C. (1997). *"Introduction to the Theory of Statistics"*. McGraw Hill, New York.
4. Lehman, E.L. (1997). *"Testing Statistical Hypotheses"*. Springer - Volga, New York.
5. Hogg, R.V. and Craig, A.T. (1996). *"Introduction to Mathematical Statistics"*. Prentice Hall, New Jersey.
6. Zacks, S. (1973), *"Parametric Statistical Inference"*, John Wiley, New York.
7. Rao, C.R., (1973). *"Linear Statistical Inference and its Applications"*, John Wiley, New York.

STAT-405 Project

OPTIONAL COURSES

STAT-406 Operations Research

History and definition of O.R. 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. Gaussian elimination. Transportation Problem, Assignment problem. Introduction to CPM and PERT techniques. Queuing Models, Inventory models, Dynamic programming and simulation models.

Books Recommended:

1. Taha, H.A. (1998). "*Operations Research*". Macmillan. London.
2. Hillier, F.S. and Lieberman G. J. (1996). "*Introduction to Operations Research*", Holden Day.
3. Gupta, P.K. & Hira, D.S. (1994). "*Operations Research*". S. Chand & Co., New Delhi.
4. Bazarra, N.M., Jarvis J.J. and Sherali, H.D. (1990) "*Linear Programming and Network Flows*", John Wiley & Sons, 2nd ed.
5. Ravindran, A., Philips, D.J and Sillerg, J.J. (1987). "*Operations Research: Principles and Practice*" John Wiley.
6. Bronson, R. (1983). "*Operations Research – Schaums' Outline Series*" – McGraw Hill.

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. The Wiener Process. Diffusion Equations for the Wiener Process.

Books Recommended

1. Ross, S. (1996). "*Stochastic Process*", 2nd Edition, John Wiley, New York.
2. Feller, W. (1992). "*An Introduction to Probability Theory and its Applications*", John Wiley, New York.

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

STAT-408 Reliability Analysis

Basic concepts of reliability. Structural reliability. Lifetime 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, 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.

Books Recommended

1. Achintya Haldar, Sankaran Mahadevan (2000). *Reliability Assessment Using Stochastic Finite Element Analysis*".
2. Crowder, M.J. (1994). "*Statistical Analysis of Reliability Data*".
3. Lee, J. Bain, Bain Bain, (1991). "*Statistical Analysis of Reliability and Life-Testing Models*".
4. Gertsbakh, I.B. (1989). "*Statistical Reliability Theory*". Marcel Decker. New York.
5. Lawless, J.F. (1982). "*Statistical Model and Methods for Lifetime Data*".
6. Gertsbakh, I.B. (1988). "*Statistical Reliability Theory*".
7. Mann, N.R., Scheefer, R.E. and Singapoor wel, N.D. (1974). *Methods for Statistical Analysis of Reliability*, John Wiley & Sons.

STAT-409 Time Series Analysis and Forecasting

Stochastic Process, Stationary Time-Series, Exponential smoothing techniques, auto-correlation and auto-covariance, estimates functions and standard error of the auto-correlation function (ACF) and PACF, Periodogram, spectral density functions, comparison with ACF, Linear stationary models: Auto regressive, Moving Average and mixed models, Non-stationary models, general ARIMA notation and models, minimum mean square forecasting. ARIMA Seasonal Models.

Books Recommended

1. Cox, D. R., Hinckley D.V. and Nielsen O.E.B. (1996). "*Time Series Models - In Econometrics, finances and other fields*"; Chapman & Hall, London.
2. Chatfield, C. (1996). "*The Analysis of Time Series: An Introduction*", Chapman and Hall, London.
3. Andy, P, West M. and Harrison, P. J. (1994). "*Applied Bayesian Forecasting and Time Series Analysis*", Chapman & Hall New York.
4. Brock well P.J. and Davis R.A. (1991). "*Time Series Theory and Methods*", Springer Verlag New York.
5. Harvey, A.C. (1990). "*Forecasting Structural Time Series Models and the Calamander*", Cambridge University Press, Cambridge.
6. Daggale, P.J. (1990), "*Time Series: A Biostatistical Introduction*", Clarendon Press, Oxford.
7. Bovas, A. and Johannes, L. (1983), "*Statistical Methods for Forecasting*", John Wiley. New York
8. Priestley, M.B. (1981), "*Spectral Analysis and Time Series*", Academic Press, London.
9. Box, G.E.P. and Jenkins, G.M. (1999). "*Time Series Analysis: Forecasting and Control*", San Francisco.

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. A prior distributions and conjugate priors. Bayes' decision procedure, admissibility of Bayes' and minimax procedures.

Books Recommended

1. Berger, J. O. (1985). "*Statistical Decision Theory & Bayesian Analysis*", Springer Verlag.
2. Lindgren, B.W. (1971). "*Elements of Decision Theory*, Macmillan", New York.
3. 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.

Books Recommended

1. Rousseau, P.J. and Leroy, A.M. (1987). "*Robust Regression and outlier detection*", John Wiley. New York.
2. 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.
3. Huber, P.J. (1981). "*Robust Statistics*", John Wiley, New York.

STAT-412 Official Statistics

Design and planning of a Statistical Investigation. Data collection-approach and operation; Role of sampling in generation of Statistics, Sampling plans and survey Designs. Sources of Errors, Types of Errors, methods of their control. Data processing, presentation, and publication of Statistics. Different modes of Data Dissemination. Official Statistics, Statistical systems and standards, Sources of official statistics, their role, working and publication. Role of Official Statistics, Official Publications.

Setup of official organizations in Pakistan their role, working & publication, Statistics Division, Federal Bureau of Statistics, Agricultural Census Organization, Population Census Organization, Ministry of Food, Agriculture and Livestock; National Data Base and Registration Authority (NADRA). Provincial Bureaus of Statistics. Financial Statistics: Ministry of Finance, State Bank of Pakistan-Department of Statistics, their working, publications and responsibilities. Other Organization's Statistical output, National and International series, 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, use of Index Numbers. and time series. Deflation and Inflation of series. National sample surveys and censuses conducted in Pakistan.

Assignment: Visit of major Statistical Organizations will be a part of the course. An assignment will have to be submitted on any topic given by the course incharge.

Books Recommended:

1. Kish, L. (1992). "*Survey Sampling*", John Wiley, New York.
2. Statistics Division, "*Activity Report*" (1988-89). *Government of Pakistan*, Islamabad.

3. Statistical Institute for Asia & Pacific SIAP (1984). "*Training of Trainers in Statistical Operations and Procedures*" Part-I, II UNDP, Tokyo.
4. 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.
5. Murthy, M.N. (1979). "*Quality of Data, Country Course on Sample Surveys*", Karachi.
6. Statistics Division (1979). "*Retrospect, Perspective and Prospect*", Islamabad.
7. State Bank of Pakistan (1966). "*Deptt. of Statistics-A Chronicle*".
8. Zarkovich S.S. (1966) "*Quality of Statistical Data, Food and Agricultural Organization*", The U.N. Rome.
9. NIPA (1962) "*Administrative uses of Statistics*", NIPA Res. Sr.No.2 Karachi.
10. Yates F. (1960), "*Sampling Methods for Census and Surveys*", Charles Griffin. FAO Year Books.
11. Various Publications of FBS, PCO, ACO, "*State bank of Pakistan, Ministry of Finance*" etc.

STAT-413 Survival Analysis

Special features of Survival data: Patient time and study time, Survival function and hazard function, Time dependent and censored survival data. Nonparametric procedures: Estimation of Survival function, hazard function, median and percentiles of Survival times. Confidence interval and comparison of group; stratified and log-rank tests for trend. Modeling of Survival data; hazard function modeling; its tests and confidence interval. The Waybill model for survival data. Exploratory data analysis and other models. Sample size requirement for survival study. Computer software for Survival analysis; any available software like SAS, BMDP, SPSS, GLIM, GENSTAT or S-plus.

Books Recommended

1. Lee, E.T. (1997). "*Applied Survival Analysis*", John Wiley and Sons, New York.
2. Muller, R.G. and Xian Zhou (1996). "*Survival Analysis with long-term Survivors*", John Wiley. New York.
3. Burkett, M. (1995). "*Analyzing Survival Data from Clinical Trials and Observational Studies*"; John Wiley New York.
4. Parmer M.K.B. & Macklin D. (1995). "*Survival Analysis: A Practical Approach*"; John Wiley New York.
5. Collett, D. (1994). "*Modeling Survival Data in Medical Research*". Chapman & Hall, London.
6. Lee, E.T. (1992). "*Statistical Methods for Survival Data Analysis*"; John Wiley. N.Y.

7. Eland Johnson, R. C. and Johnson N. L. (1989), "*Survival Models & Data Analysis*". John Wiley N.Y.
8. Turkey, J. (1987). "*Exploratory Data Analysis*", John Wiley, New York.
9. Cox, DR. and Oakes, D. (1984). "*Analysis of Survival Data*"; Chapman & Hall London.

STAT-414 Biostatistics

Definition of Biostatistics, viz-a-viz the 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 samples; 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.

Books Recommended

1. Zar, J. (2000). "*Biostatistical Analysis*", 5th Edition, John Wiley and Sons.
2. Shoukri, M. M. & Pause, C. A. (1998). "*Statistical Methods for Health Sciences*". 2nd Edition, CRC Press, Florida.
3. Daniel, W.W. (1996). "*Biostatistics: A Foundation for the Health Sciences*", 6th Edition, John Wiley, New York.
4. Diggle, J. P., Liang, Kung-Yee and Zeger, S. L. (1996). "*Analysis of Longitudinal Data*", Clarendon Press, Oxford.
5. Dunn, G. and Everit, B. (1995). "*Clinical Biostatistics*", Edward Arnold, London.
6. Rosner, B. (1994). "*Fundamentals of Biostatistics*", 4th Edition, Duxbury Press.
7. Zolman, J.F. (1993). "*Biostatistics: Experimental Design and Statistical Inference*", Oxford University Press, New York.
8. Lee, E.T. (1992). "*Statistical Methods for Survival Data Analysis*", 2nd Edition, John Wiley, New York.
9. Harris, E. K. and Albert, A. (1991). "*Survivorship Analysis for Clinical*"
10. "*Studies*". Marcel Decker, New York.
11. Altman, G. (1991). "*Practical Statistics for Medical Research*". Chapman & Hall, London.
12. Lawless, J. F. (1982). "*Statistical Models and Methods for Life Time Data*". John Wiley, New York.

STAT-415 Data Mining

Introduction to databases, including simple and relational databases; data warehouses. Review of classification methods from multivariate analysis; classification and decision 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.

Books Recommended

1. Han, J. and Camber, M. (2000). Data Mining; "*Concepts and Techniques*". Morgan Kaufmann.
2. Benson and Smith, S.J. (1997). "*Data Warehousing, Data Mining*", and OLAP. McGraw-Hill.
3. Mitchell, T.M. (1997). "*Machine Learning*". McGraw-Hill.
4. Ripley, B.D. (1996). "*Pattern Recognition and Neural Networks*". Cambridge University Press.
5. Breiman, L. Friedman, J.H. Olshen, R.A. and Stone, C.J. (1984). "*Classification and Regression Trees*" Wadsworth and Brooks/Cole.

STAT-416 Actuarial Statistics-I

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.

Books Recommended

1. Bowers, N.L. Gerber, H.U. Hickman, J.C. Jones, D.A. and Nesbitt, C.J. (1986). "*Actuarial Mathematics*", Society of Actuarial, Ithaca, Illinois, U.S.A. Second Edition (1997).
2. Neill, A. (1977). "*Life Contingencies*", Heineman.
3. 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.

Books Recommended

1. 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).
2. Spurgeon, E.T. (1972). "*Life Contingencies*", Cambridge University Press.
3. Neill, A. (1977). "*Life Contingencies*", Heinemann.

STAT-418 Mathematical Modeling and Simulation

Monte Carlo methods: Different methods of generating random variables, generation of random numbers, 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 techniques. Variance reduction techniques: importance sampling for integration, control variates and antithetic variables.

Books Recommended:

1. Ross, S.M.(2002). "*Simulation*" (Third Edition) (Academic)
2. Fishman, G.S. (1996). Monte Carlo: "*Concepts, Algorithms, and Applications*", (Springer).
3. Rubinstein, R.Y. (1981). "*Simulation and the Monte Carlo Method*", (Wiley).
4. Ripley, B.D. (1987) "*Stochastic Simulations*" (Wiley)

STAT-419 Categorical Data Analysis

Introduction, describing two way contingency tables, inference for two way contingency tables, models for binary response variables, Log linear models, fitting Log linear and Logit models, building and applying Log linear models, Log linear Logit models for ordinal variables, multinomial response models for matched pairs, analyzing repeated categorical response data, logistic regression models and their analysis.

Books Recommended

1. Agresti, A. (1990), "*Categorical Data Analysis*", John Wiley and Sons.
2. Bishop, Y.V.V., Fienberg, S.E. and Holland, P.W. (1975). "*Discrete Multivariate Analysis*", MA: MIT Press Cambridge.
3. Cox, D.R. and Snell, E.J.(1989). "*The Analysis of Binary Data*", Chapman and Hall, London.
4. David, W.H., Leweshow, S.L. (1989). "*Applied Logistic Regression*".
5. Mc Gullah, P. and Nelder, J.A. (1989). "*Generalized Linear Models*", 2nd ed. Chapman and Hall, London.

MS STATISTICS (2 Years program)

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	# of Subject	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	Theory of Estimation	(3 cr.hrs.)
Stat-702	Linear Models and Regression Analysis-I	(3 cr.hrs.)
Stat-703	Hypothesis Testing	(3 cr.hrs.)
Stat-704	Linear Models and Regression Analysis-II	(3 cr.hrs.)
Stat-705	Advanced Probability Theory	(3 cr.hrs.)
Stat-706	Advanced Design of Experiments	(3 cr.hrs.)
Stat-707	Multivariate Analysis-I	(3 cr.hrs.)
Stat-708	Multivariate Analysis-II	(3 cr.hrs.)
Stat-709	Time Series and Forecasting	(3 cr.hrs.)
Stat-710	Categorical Data Analysis	(3 cr.hrs.)
Stat-711	Logical Reasoning and Research Methods	(3 cr.hrs.)
Stat-712	Advance Sampling Techniques	(3 cr.hrs.)
Stat-713	Measure Theory	(3 cr.hrs.)
Stat-714	Survival Data Analysis	(3 cr.hrs.)
Stat-715	Applied Stochastic Models	(3 cr.hrs.)
Stat-716	Spatial Data Analysis	(3 cr.hrs.)
Stat-717	Advance Theory of Statistics	(3 cr.hrs.)
Stat-718	Inference in Stochastic Processes	(3 cr.hrs.)
Stat-719	Bayesian Analysis	(3 cr.hrs.)
Stat-720	Optimization Techniques	(3 cr.hrs.)
Stat-721	Statistical Ecology	(3 cr.hrs.)
Stat-722	Medical Statistics	(3 cr.hrs.)
Stat-723	Analysis of Clinical Trials	(3 cr.hrs.)

Stat-724	Stochastic Models in Finance	(3 cr.hrs.)
Stat-725	Genetic Data Analysis	(3 cr.hrs.)
Stat-726	Generalized Linear Models	(3 cr.hrs.)
Stat-727	Analysis of Repeated Measures	(3 cr.hrs.)
Stat-728	Probability Distributions-I	(3 cr. hrs)
Stat-729	Probability Distributions-II	(3 cr. hrs)
*Stat-730	Advance Statistical Methods for Reliability	(3 cr.hrs.)
*Stat-731	Advance Statistical Methods for Quality Control	(3 cr.hrs.)
*Stat-732	Actuarial Statistics	(3 cr.hrs.)
*Stat-733	Operations Research	(3 cr.hrs.)
*Stat-734	Geo-Statistics	(3 cr.hrs.)
*Stat-735	Environmental Statistics	(3 cr.hrs.)
*Stat-736	Bio-Informatics	(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 Theory of Estimation (3 cr.hrs.)

Estimation: Introduction; Statistical Models, Estimation and Properties, Finite Sample Properties and asymptotic properties. Exponential family. Sufficient statistics, Minimal sufficient Statistics, Complete Sufficient Statistics. Cramer Rao lower bound. Rao- Blackwell theorem. Lehmann-Scheffe theorem. UMVUE, Consistency and BAN.

Point Estimation Methods; Introduction: Least squares and General Linear Model (GLM). The classical GLM assumptions Estimation for unknown Parameters under classical GLM assumption, Estimation for Variance under Classical GLM assumptions. Consistency of estimators, Consistency of the Estimator of Variance. Asymptotic normality of estimators of unknown parameters and their variances. Violation of classical GLM Assumption Least Square under normality. Least Square for ordered data. Method of Maximum Likelihood Estimation (MLE), properties of MLE for finite samples and large samples. Method of moments and its properties. Generalized Method of moments and its Properties, Chi-square and modified Chi-square method of estimation.

Baye's Estimation ; Computing posterior distributions, Loss function, risk function, decision function, Baye's estimators, admissibility. Minimax Estimators.

Books Recommended

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-702 Linear Models and Regression (3 cr.hrs.)
Analysis-I

Definition and forms of linear models. Functionally related models, mean related model and model classification, Generalized Linear Models. Least squares and unbiased estimation. Best Linear Unbiased Estimation. Multiple Regression Analysis. Various approaches of subset selection procedures, Heteroscedasticity, Autocorrelation, Multicollinearity, Ridge Regression, Properties of the Ridge Estimator and Choice of Biasing Parameters k , Computational Shortcuts for ordinary Ridge estimators, Predictions from Regression. Choosing a Regression Model.

Books Recommended

1. Annette J. Dobson. (2001). *An Introduction to Generalized Linear Models*. Text in Statistical Science.
2. Baltagi, B. H. (1999). *Econometrics*. Springer Varlog, 2nd Edition.
3. Christensen, J. (2002). *Advanced Linear Modeling*. Springer Texts in Statistics
4. Draper, N.R. and Smith, H (2004). *Applied Regression Analysis*. John Wiley and Sons.
5. Graybill F.A. (1990). *An Introduction to Linear Statistical Models*. McGraw Hill Book Company Inc. New York.
6. Gujrati. D. (2003). *Econometrics*, John Wiley, New York.
7. Harrell, F. E. (2003). *Regression Modeling Strategies*. Springer Texts in Statistics.
8. Kshirsagar, A.M. (1983). *A Course in Linear Models*. Mareel Dekker, New York.
9. McCulleggh P. and Nelder J.A. (1990). *Generalized Linear Models*. Chapman and Hall, New York.
10. Miller, A.J. (1990). *Subset Selection in Regression*. Chapman and Hall, London.
11. Montgomery, D.C., and Peck E.A. (1992). *Introduction to Linear Regression Analysis*. John Wiley and sons Inc. New York.
12. Rawlings, J. O., Pantula, S. G., Dickey, D. A. (2001). *Applied Regression Analysis*. Springer Texts in Statistics
13. Weisburg, S. (1980). *Applied Linear Regression*. John Wiley and Sons.

STAT-703 Hypothesis Testing and Interval Estimation

(3 cr.hrs.)

Elements of Hypothesis - Testing Theory; Introduction: Statistical hypotheses, Testing concepts, Statistical hypothesis tests, Type I error & Type II error, Controlling type I & II errors, Test Statistics, null and alternative hypothesis. Power function, Properties of statistical tests. P-Value, Asymptotic tests, Neyman Pearson Lemma, Monotone-Likelihood Ratio Approach, Exponential Class of densities.

Hypothesis testing methods; Generalized Likelihood Ratio tests. Asymptotic properties of Generalized Likelihood Ratio test. Lagrange's Multiplier Tests, Wald Test, Tests in GLM.

Confidence intervals and regions, Confidence regions from pivotal quantities. Bayesian Interval estimation. Confidence regions as hypothesis testing.

Inferences Concerning a Cumulative Distribution Function, Inferences Concerning Quantiles, Tolerance Limits, Equality of Two Distributions.

Books Recommended

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.

Outlier Diagnostics: The Hat Matrix and L S Residuals, Single and Multiple-case Diagnostics, Recent Developments, High-Breakdown Diagnostics.

Stein-Rule Shrinkage Estimator: Motivation for Shrinkage: Stein-Rule in the Regression Context, Properties of the Stein-Rule Estimator and its Extensions.

Robust Regression for Non-normal Errors, Testing a Nonlinear Specification, Measures of Nonlinearity.

Orthogonality, Distribution of Quadratic forms.

Resampling Techniques: Jackknifing, Bootstrapping.

Books Recommended

1. Annette J. Dobson. (2001). *An Introduction to Generalized Linear Models*. Text in Statistical Science.
2. Baltagi, B. H. (1999). *Econometrics*. Springer Varlog, 2nd Edition.
3. Christensen, J. (2002). *Advanced Linear Modeling*. Springer Texts in Statistics
4. Draper, N.R. and Smith, H. (2004). *Applied Regression Analysis*. John Wiley and Sons.
5. Graybill F.A. (1990). *An Introduction to Linear Statistical Models*. McGraw Hill Book Company Inc. New York.
6. Gujrati. D. (2003). *Econometrics*, John Wiley, New York.
7. Harrell, F. E. (2003). *Regression Modeling Strategies*. Springer Texts in Statistics.
8. Kshirsagar, A.M. (1983). *A Course in Linear Models*. Mareel Dekker, New York.
9. McCulleggh P. and Nelder J.A. (1990). *Generalized Linear Models*. Chapman and Hall, New York.
10. Miller, A.J. (1990). *Subset Selection in Regression*. Chapman and Hall, London.
11. Montgomery, D.C., and Peck E.A. (1992). *Introduction to Linear Regression Analysis*. John Wiley and sons Inc. New York.
12. Rawlings, J. O., Pantula, S. G., Dickey, D. A. (2001). *Applied Regression Analysis*. Springer Texts in Statistics
13. Rousseew, P.J. and Leroy A.M. (1987). *Robust Regression and Outlier Detection*. John Wiley and Sons.
14. Weisburg, S. (1980). *Applied Linear Regression*. John Wiley and Sons.

STAT-705 Advanced Probability Theory

(3 cr.hrs.)

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 a.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.

Books Recommended

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. Loeve, M. (1978), *Probability Theory*, 4th ed., Springer Verlag.
5. Gnedenko, B.V. (1988), *Probability Theory*, Mir Pub.
6. Stuart A. and Ord J. K. (1998) *Advanced Theory of Statistics*, Volume I: *Distribution Theory*. 6th Ed, Edward Arnold

STAT-706 Advanced Design of Experiments

(3 cr.hrs.)

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

Books Recommended

1. Dey, A. (1986), *Theory of Block Designs*, Wiley Eastern Ltd. New Delhi
2. Cochran, W.G. and Cox, G.M. (1992), *Experimental Design*, Wiley International.
3. John, J.A. (1987), *Cyclic Design*, Chapman and Hall, London
4. Kenward, M.G. and Jones, B. (1989), *Design and Analysis of Cross-over Trails*.

5. Myres, R.H. and Montgomery, D.C. (1995), *Response Surface Methodology: Process and Product Optimization using Designed Experiments*, John Wiley and Sons.
6. Montgomery D.C. (2000). *Design and Analysis of Experiments*, John Wiley, NY.
7. Clarke, G.M., and Kempton, R.E. (1997), *Introduction to the Design & Analysis of Experiments*, Edward Arnold.
8. Boniface, D.R. (1995). *Experiment Design & Statistical Methods*, Chapman & Hall.
9. Myers, R.H. and Montgomery, D.C. (1995). *Response Surface Methodology; Process & Product Optimization using design*, John Wiley.
10. Harold, R. L (1992) *Analysis of Variance in Experimental Design*. Springer Verlag:
11. Maxwell, S.E. and Delaney, H.D. (1990). *Designing Experiments and Analysis of Data. A model comparison perspective*. Belmont and Wadson.
12. Mead, R. (1988). *The Design of Experiments*. Cambridge University Press, Cambridge.
13. Das, M.N.and Giri, N.C, (1986). *Design and Analysis of Experiments*, John Wiley, New York.
14. Khuri, A. I. and Cornell, J. A. (2001) *Response Surfaces; design and Analysis*, 2nd ed, CRC Press, USA.
15. Box G. E. P. & Draper N. R., (1998) *Evolutionary Operation: A statistical Method for Process Improvement*, Wiley Classic Library, USA.

STAT-707

Multivariate Analysis-I

(3 cr.hrs.)

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.

Books Recommended

1. Johnson, R.A. and Wincher, D.W. (2004). *Applied Multivariate Statistical Analysis*. Prentice Hall. London.
2. Sharma, S. (1996), *Applied Multivariate Techniques*, John Wiley and Sons, New York.
3. Tabachnick, B.G and Fidell, L.S. (1996), *Using Multivariate Statistics*, 3rd ed. Harper Collins College, Publishers.
4. 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.

5. Flurry B. (1997) *A First Course in Multivariate Statistics*, Springer Valerg, New York.
6. Morrison. F. (1990). *Multivariate Statistical Methods*, McGraw Hill, New York.
7. Manly, B.F.J. (1994). *Multivariate Statistical Methods, A Primer* 2nd Edition, Chapman and Hall, London.
8. Anderson, T.W. (2003). *An Introduction to Multivariate Statistical Analysis*, John Wiley, New York.
9. Chatfield, C. and Collins, A.J. (1980). *Introduction to Multivariate Analysis*, Chapman and Hall, London.
10. Mardia, K.V., Kent, J.T. and Bibby, J.M. (1979). *Multivariate Analysis*, Academic Press, London.
11. Everett, B.J. (1974). *Cluster Analysis*, McGraw Hill, New York.
12. Afifi, A. A. and Clark Virginia (1984). *Computer Aided Multivariate Analysis*, Lifetime learning publications, Belmont California.

STAT-708

Multivariate Analysis-II

(3 cr.hrs.)

Principal Component Analysis, Factor Analysis, Discriminant Analysis. Canonical Correlation. Cluster analysis, Path analysis. Multivariate Analysis of variance (MANOVA).

Books Recommended

1. Sharma, S. (1996), *Applied Multivariate Techniques*, John Wiley and Sons, New York.
2. Tabachnick, B.G and Fidell, L.S. (1996), *Using Multivariate Statistics*, 3rd ed. Harper Collins College Publishers.
3. 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.
4. Flurry B. (1997) *A First Course in Multivariate Statistics*, Springer Valerg, New York.
5. Johnson, R.A. and Wincher, D.W. (2004). *Applied Multivariate Statistical Analysis*. Prentice Hall. London.
6. Morrison. F. (1990). *Multivariate Statistical Methods*, McGraw Hill, New York.
7. Manly, B.F.J. (1994). *Multivariate Statistical Methods, A Primer* 2nd Edition, Chapman and Hall, London.
8. Anderson, T.W. (2003). *An Introduction to Multivariate Statistical Analysis*, John Wiley, New York.
9. Chatfield, C. and Collins, A.J. (1980). *Introduction to Multivariate Analysis*, Chapman and Hall, London.
10. Mardia, K.V., Kent, J.T. and Bibby, J.M. (1979). *Multivariate Analysis*, Academic Press, London.

11. Everett, B.J. (1974). *Cluster Analysis*, McGraw Hill, New York.
12. Afifi, A. A. and Clark Virginia (1984). *Computer Aided Multivariate Analysis*, Lifetime learning publications, Belmont California.

STAT-709 Time Series and Forecasting (3 cr.hrs.)

Definition of time series, stationary and non stationary time series, how model arise, meaning and estimation of ACF and PACF. Linear stationary and non stationary models. Autoregressive form of ARMA model. Model identification. Minimum mean squares forecasts. Forecasting using state space model and use of Kalman filter series model. Estimation of models smoothing, reliability analysis of forecast error. Transfer function, intervention analysis and Spectral analysis.

Recommended Books

1. Box, G.E.P. and Jenkins, G.M. (1976), *Time Analysis, Forecasting and Control*, 2nd ed., Holden Day, San Francisco.
2. Chatfield, C. (1980), *The analysis of Time Series: An Introduction*, Chapman and Hall.
3. Diggle, P.J. (1990), *Time Series: An Bio-statistics Introduction*, Oxford University Press.
4. Kendall, M. and Ord, J.K (1976) *Time Series*, 2nd ed., Hafner, New York.
5. Kendall, M. and Stuart, A and Ord, J.K. (1983) *Advance Theory of Statistics*, Vol-3.
6. Montgomery, D.C., Johnson, L.A. and Gradiner, J.S.(1990), *Forecasting and Time Series Analysis*, McGraw Hill Inc. Edition.

STAT-710 Categorical Data Analysis (3 cr.hrs.)

Introduction, describing two way contingency tables, inference for two way contingency tables, models for binary response variables, Log linear models, fitting Log linear and Logit models, building and applying Log linear models, Log linear, Probit and Logit models, multinomial response models for matched pairs, analyzing repeated categorical response data, logistic regression models and their analysis.

Books Recommended

1. Agresti, A. (1990), *Categorical Data Analysis*, John Wiley and Sons.
2. Bishop, Y.V.V., Fienberg, S.E. and Holland, P.W. (1975), *Discrete Multivariate Analysis*, MA:MIT Press Cambridge.
3. Cox, D.R. and Snell, E.J.(1989), *The Analysis of Binary Data*, Chapman and Hall, London.
4. David, W.H., Leweshow, S.L. (1989), *Applied Logistic Regression*

5. Mc Gullah, P. and Nelder, J.A. (1989), *Generalized Linear Models*, 2nd ed. Chapman and Hall, London.

STAT-711 Logical Reasoning and Research Methods (3 cr.hrs.)

Propositions and arguments, recognizing arguments, validity and invalidity, fallacies. Definitions and its types, 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.

Books Recommended

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-712 Advance Sampling Techniques (3 cr.hrs.)

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 Scales, Guttman Scales, Semantic Differential, A Survey of Super population Models. Randomization theory results for SRS Model for SRS 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 Serves, Effects of Survey Design on Regression Analysis, Effects of Two-stage Sampling on OLS Methods, Comparison of Domain Means in Two-stage Sampling.

Books Recommended

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-713 Measure Theory (3 cr.hrs.)

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.

Books Recommended

1. Barru, G.D. (1981), *Measure Theory and Integration*, Ellis, Harwood Ltd.
2. Folland, G.B. (1984), *Real Analysis-Modern Techniques and their Applications*, John Wiley and Sons.
3. Khan, A.R. (1993) *Introduction to Lebesgue Integration*, Illmi Kitab Khana, Lahore.
4. Roydon, H.L. (1968) *Real Analysis*, Collier Macmillan Co. New York.
5. Rudin, W. (1980) *Real and Complex Analysis*, McGraw Hill.

STAT-714 Survival Data Analysis (3 cr.hrs.)

Multiparameter analysis using large sample likelihood methods for response time data, survival function and hazard function, multiparameter models, reparameterization and regression-type models, likelihood functions for censored data, Kaplan-Meier (Product-limit) estimation, testing based on maximum likelihood estimators, likelihood ratios and score tests. Computational methods including the EM. Algorithm, partial likelihood methods for proportional hazards, analysis of grouped data.

Books Recommended

1. Bain, L.J. (1978) *Statistical Analysis of Reliability and Life-Testing Models*, Marcel Dekker.

2. Lawless, J.F. (1982) Statistical Models and Methods for Lifetime Data, John Wiley and Sons.
3. Lee, E.T. Statistical Methods for Survival Data Analysis, John Wiley and Sons.

STAT-715 Applied Stochastic Models (3 cr.hrs.)

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.

Books Recommended

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-716 Spatial Data Analysis (3 cr.hrs.)

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.

Books Recommended

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-717 Advance Theory of Statistics (3 cr.hrs.)

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

Books Recommended

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-718 Inference in Stochastic Processes (3 cr.hrs.)

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 CLT 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.

Books Recommended:

1. Billingsley, P. (1962) Statistical Inference for Markov chains, (Chicago University Press).

2. Basawa, I.V. and Prakasa Rao, B.L.S.(1980) Statistical Inference for Stochastic Processes, (Academic Press).
3. Adke, S.R. and Manjunath, S.M.(1984) An introduction to Finite Markov Processes, (Wiley Eastern).
4. Gutterp, P. (1991) Statistical Inference for Branching Processes, (Wiley).
5. Gutterp, P.(1995) Stochastic Modelling for Scientific Data, (Springer).
6. Bhat, B.R.(2000) Stochastic models : Analysis and Applications, (New Age International Publishers).
7. Prakasa Rao, B.L.S. and Bhat, B.R.(1996) Stochastic Processes and
8. Statistical Inference, New Age International Publisher.

STAT-719 Bayesian Analysis (3 cr.hrs.)

Formulation of a decision problem: randomized and non-randomized decision rules, risk function, optimality of decision rules. Utility theory and loss function. Subjective probability and selection of prior distribution for Bayesian analysis. Bayesian analysis for statistical inference problems of estimation, testing hypotheses, confidence interval and prediction. Bayesian decision theory. Admissible and minimax decision rules. Complete class of decision rules.

Books Recommended:

1. James O. Berger (1985), Statistical Decision Theory and Bayesian Analysis,(Second Edn.) Springer –Verlag
2. DeGroot M. H. (1970) Optimal Statistical Decisions
3. Ferguson, T.S. (1967) Mathematical Statistics : A Decision Theoretic Approach. Academic Press.

STAT-720 Optimization Techniques (3 cr.hrs.)

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 LPP.

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.

Books Recommended:

1. Kambo, N.S.(1991) Mathematical Programming Techniques Affiliated East-West Press Pvt.Ltd.)
2. Hadley,G. (1987) Linear Programming.
3. Taha, H.A.(1992) Operations Research 5th ed. (Macmillan)

STAT-721 Statistical Ecology (3 cr.hrs.)

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.

Books Recommended:

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

STAT-722**Medical Statistics****(3 cr.hrs.)**

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.

Books Recommended:

1. Selvin: Statistical analysis of epidemiological data.
2. Diggle, Liang and Zeger : Analysis of longitudinal data
3. Piantadosi: Clinical trials
4. Agresti: Categorical Data Analysis.
5. Clayton and Hills: Statistical methods in Epidemiology
6. McCullagh and Nelder: Generalized Linear Models.
7. Brookemeyer and Gail: AIDS Epidemiology: A Quantitative Approach
8. Zhou, Obuchowski and McClish: Statistical Methods in Diagnostic Medicine

STAT-723**Analysis of Clinical Trials****(3 cr.hrs.)**

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.

Books Recommended:

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

STAT-724 Stochastic Models In Finance (3 cr.hrs.)

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.

Books Recommended:

1. John Hull L: Options, futures and other derivatives(Prentice Hall)
2. M.Baxter and A.Rennie L: Financial Calculus(Cambridge, 1996)
3. N.Bingham and R.Keisel : Risk-Nuetral Valuation(Springer)

STAT-725 Genetic Data Analysis (3 cr.hrs.)

Analysis of discrete data, illustrated with genetic data on morphological characters allozymes, restriction fragment length polymorphisms and DNA sequences. Maximum likelihood estimation, including iterative procedures. Numerical resembing. Development of statistical techniques for characterizing genetic disequilibrium and diversity. Measures of population structure and genetic distance. Construction of phylogenetic trees. Finding alignments and similarities between DNA sequences. Locating genes with markers.

Books Recommended

1. C.C.Li (1976).First course on population genetics. Boxwood Press, California.
2. W.J.Ewens (1979).Mathematical population genetics. Springer Verlag.
3. T.Nagylaki (1992).Introduction to theoretical population genetics. Springer Verlag.
4. R.Durbin,S.R.Eddy,A.Krogh,G.Mitchison (1998).Biological Sequence Analysis:
5. Probabilistic Models of Proteins and Nucleic Acids.
6. R.C.Elandt -Johnson (1975).Probability Models and Statistical Methods in Genetics.

STAT-726

Generalized Linear Models

(3 cr.hrs.)

Logistic and Poisson regression: Logit model for dichotomous data with single and multiple explanatory variables, ML estimation, large sample tests about parameters, goodness of fit, analysis of deviance, variable selection, extension to polytomous data, introduction to Poisson regression.

Linear models for two and three dimensional contingency tables: interpretation of parameters, comparison with ANOVA and regression, ML estimation of parameters, likelihood ratio tests for various hypotheses including independence, marginal and conditional independence, partial association, models with quantitative levels.

Nonparametric regression and generalized linear models: interpolating and smoothing splines for simple regression, use of cross-validation, applications to logistic and Poisson regression introduction to additive models and generalized additive models.

Books Recommended

1. D.W. Hosmer and S. Lemeshow (2000). Applied Logistic Regression, Second edition. Wiley, New York.
2. Agresti (1990). Categorical Data Analysis. Wiley, New York.
3. R. Christensen (1997). Log-linear Models and Logistic Regression, Second edition. Springer, New York.
4. P. McCullough and J.A. Nadler (1999). Generalized Linear Models, Second edition. Chapman and Hall, New York.
5. P.J. Green and B.W. Silverman (1994). Nonparametric Regression and Generalized Linear Models. Chapman and Hall, New York.
6. T.J. Hastie and R.J. Tibshirani (1999). Generalized Additive Models. Second edition. Chapman and Hall, New York.

STAT-727 Analysis of Repeated Measures (3 cr.hrs.)

Introduction of repeated measures designs, models and assumptions, variants– 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.

Books Recommended

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

STAT-728 Probability Distribution-I (3 cr.hrs.)

Random variable, Density functions, Distribution functions, Independent random variables and convolution.

Bivariate normal, exponential, Weibull, gamma, Burn, Beta-Binomial distributions and their applications, Conditional distributions

Expectations of random variables, Moments and Cumulants, Conditional Expectations, Characteristic Functions

Books Recommended:

1. Fraser, D. A. S. (1976), "Probability and Statistics: Theory and Applications", Duxbury Press, Massachusetts.
2. Elderton, W. P. (1969), "Systems of Frequency Curves", Cambridge University Press, London.
3. Johnson, N. L., et al (1994), "Continuous Univariate distributions – Vol. 2", Wiley.
4. Wilks, S. S. (1963), "Mathematical Statistics", Wiley
5. Rao, C. R. (1974), "Linear Statistical Estimation and its Applications", Wiley
6. Stuart A. and Ord J. K. (1991), "Kendall's Advanced Theory of Mathematical Statistics – Vol I", Charles Griffen and Co., London

7. Kotz, S., Balakrishnan, N. and Johnson, N. L. (2000), "Continuous multivariate distributions – Volume 1, Models and Applications, 2nd Ed.", Wiley
8. Ross, S. M. (2002), "Introduction to Probability Models, Eighth Edition", Academic Press.
9. Ross, S. M. (2005), "A First Course in Probability", Prentice Hall

STAT-729 Probability Distribution-II (3 cr.hrs.)

Sampling Transformation of random variables and their distributions. Non-central χ^2 , t and F distributions. Distribution of Fisher's Z statistic and linear sample correlation coefficient for uncorrelated normal data.

Limiting Distributions: Weak and Strong laws of large numbers, The central limit theorem.

Some families of Distributions: Pearson, Johnson, and Burr families.

Characteristics function of Distributions in R^k .

Independence of mean vector and the quadratic form of normal variables.

Books Recommended:

1. Fraser, D. A. S. (1976), "Probability and Statistics: Theory and Applications", Duxbury Press, Massachusetts.
2. Elderton, W. P. (1969), "Systems of Frequency Curves", Cambridge University Press, London.
3. Johnson, N. L., et al (1994), "Continuous Univariate distributions – Vol. 2", Wiley.
4. Wilks, S. S. (1963), "Mathematical Statistics", Wiley
5. Rao, C. R. (1974), "Linear Statistical Estimation and its Applications", Wiley
6. Stuart A. and Ord J. K. (1991), "Kendall's Advanced Theory of Mathematical Statistics – Vol I", Charles Griffen and Co., London
7. Kotz, S., Balakrishnan, N. and Johnson, N. L. (2000), "Continuous multivariate distributions – Volume 1, Models and Applications, 2nd Ed.", Wiley
8. Ross, S. M. (2002), "Introduction to Probability Models, Eighth Edition", Academic Press.
9. Ross, S. M. (2005), "A First Course in Probability", Prentice Hall

Recommendations

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

1. Departments of Statistics in the universities should make efforts to interact with the statistical organizations, industry and other users of statistics in the public and private sector.
2. Internship should be funded by the HEC and offered to students in the 7th semester in B.S programme.
3. Most of the courses must involve problem solving using computers.
4. Highly qualified statisticians are in short supply in Pakistan. There is a need of giving extra quota for statistics students for higher education in foreign countries leading to Ph.D. degree. HEC is therefore, impressed upon to give extra scholarships to statistics graduates.
5. The committee strongly recommends the creation of “Department of Biostatistics” for teaching and research guidance at all medical colleges/universities and the post of biostatistician in all hospitals.
6. Practicals conducted during the first 2 years for BS programme should be in the form of case studies. Secondary data published by different organizations may be used in such case studies.
7. Statistics at the intermediate (F.A./F.Sc.) level should also be taught in all the colleges of all the provinces.
8. Each university should create a Centre of Excellence so that a student who wishes to specialize in a specific field should know the best possible university to join.
9. Refresher courses at post-graduate level should be regularly arranged by the HEC.
10. HEC may support universities for the development of computer labs, departmental libraries, students and staff participation in seminars.