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UNIVERSITY OF THE PUNJAB

NOTIFICATION

It is hereby notified that the Syndicate at its meeting held on 15-11-2021 has approved the recommendations of the Committee constituted by the Academic Council at its meeting dated 04-01-2021 regarding approval of the revised Syllabi & Courses of Reading for M.Phil and Ph.D. in Statistics w.e.f. the Academic Session, 2020 and onward.

The revised Scheme of Studies/Syllabi & Courses of Reading are enclosed herewith, Vide Annexure-A&B.

Sd/-

Dr. Muhammad Khalid Khan
Registrar

Admin. Block,
Quaid-i-Azam Campus,
Lahore.
No. D/ 12244 /Acad.

Dated: 28-12-/2021.

Copy of the above is forwarded to the following for information and further necessary action: -

1. Dean, Faculty of Sciences.
2. Principal, College of Statistical & Actuarial Sciences.
3. Chairperson, DPCC.
4 Controller of Examinations
7. Director, Quality Enhancement Cell
8. Director, IT.
7. Admin. Officer (Statutes)
8. Secretary to the Vice-Chancellor.
9. Secretary to the Pro-Vice Chancellor
10. P.S. to the Registrar
11. Assistant Syllabus.

Assistant Registrar (Academic)
for Registrar

Scheme of Studies:

M.Phil. / PhD
in
Statistics

College of Statistical and Actuarial Sciences,
University of the Punjab, Lahore

Program Title: M.Phil. / PhD in Statistics

Department: College of Statistical and Actuarial Sciences

Faculty: Science

1. Mission and Vision

We are committed to the advancement of statistical methods by applying new techniques and exploring their applications in society and industry. Our mission is to train our students with the modern statistical knowledge and to prepare them for the challenges of modern world.

2. Introduction

The subject of statistics was introduced in the University of the Punjab at the undergraduate and post-graduate levels in 1941. In 1950, the Department of Statistics was established by late Dr. M. Zia ud Din. In the same year in addition to postgraduate diploma course, a two-year Master's Degree Program in Statistics was started. In 1952, the Department was upgraded to the status of the institute. Since its inception, the institute has been engaged in individual and collective research in the field of theoretical and applied statistics. In 2007, the Institute of Statistics was upgraded to the College of Statistical and Actuarial Sciences.

3. Program Introduction (M.Phil. / PhD in Statistics)

The M.Phil. / Ph.D. program provides basic research training which motivates scholars to go into high quality research and Post-Doc like programs. This ultimately helps to prepare scientific/educational manpower with depth of scholarship and research competence of international level to fill senior positions in research organizations, industry, management, universities and educational institutions. This also improves the qualification of teachers and thus provides competent teachers at all levels of education in universities, colleges and schools.

4. Program Objectives

The objectives of the courses/modules contained in the program are given as:

1- To educate students regarding the major tenets of statistics both in applied and theoretical statistics.

2- To prepare them for the job market by teaching them statistical packages and programming languages.

3- To advise them about designing, carrying out and presenting an original and publishable work of research at the leading edge of statistics.

4- To provide them with rigorous classroom training in theory, methodology, and application of statistics, and provide them the opportunity to work with faculty on advanced research topics.

5- To train them regarding explaining their work orally and identifying areas of future research in statistics.

5. Admission Eligibility Criteria

- For M.Phil. in Statistics, BS/M.Sc. Statistics or equivalent
- For PhD in Statistics, M.Phil. Statistics or equivalent

6. Duration of the Program

M.Phil.	**Years**	**Semesters**	**Courses**	**Credit Hours**
Coursework	1	2	8	24
Dissertation	1	---	---	06
Total	2	---	---	30

Ph.D.	**Years**	**Semesters**	**Courses**	**Credit Hours**
Coursework	1	2	6	18
Dissertation	As per HEC criteria			

7. Scheme of Studies:

M.Phil. in Statistics

Course Title	Credit Hours	Code
SEMESTER-I		
Advanced Research Methods	3	STAT-501
Structural Equation Models	3	STAT-504
Machine Learning	3	STAT-503
Advanced Multivariate Analysis	3	STAT-508
Semester's Total Credits	**12**	
SEMESTER-II		
Advanced Statistical Computing	3	STAT-502
Multilevel Models	3	STAT-506
Metaheuristic Algorithms	3	STAT-507
Spatial Statistics	3	STAT-505
Semester's Total Credits	**12**	
DISSERTATION		
One year		
Total Credits Dissertation	**6**	

Ph.D. in Statistics

Course Title	Credit Hours	Code
SEMESTER-I		
Advanced Research Methods	3	STAT-501
Optimization Techniques	3	STAT-510
Advanced Multilevel Models	3	STAT-619
Semester's Total Credits	**9**	
SEMESTER-II		
Advanced Statistical Computing	3	STAT-502
Generalized Linear Models	3	STAT-511
Meta-Analysis	3	STAT-512
Semester's Total Credits	**9**	
DISSERTATION		
As per HEC criteria		

8. Award of Degree

As per Punjab University Rules & Regulations

9. NOC from Professional Councils (If Applicable)

Not Applicable

10. Faculty Strength

Degree	Area /Specialization	Total
PhD	1. Prof. Dr. Sohail Chand (Statistical Modeling) 2. Dr. Rehan Ahmad (Applied Statistics) 3. Dr. Maryam Ilyas (Statistical Modeling) 4. Dr. Sana Saeed (Data Science) 5. Prof. (R) Dr. Shahid Kamal (Biostatistics) 6. Prof. (R) Dr. Ahmad Saeed Akhter (Mathematical Statistics)	(06)
M.Phil.	1. Mr. Munawar Iqbal (Mathematical Statistics) 2. Ms. Irum Dar (Applied Statistics) 3. Ms. Aasma Riaz (Applied Statistics) 4. Ms. Nadia Saeed (Applied Statistics) 5. Ms. Shumaila Abbas (Applied Statistics) 6. Mr. Samar Abbas (Computer Science and Data Science) 7. Mr. Ghulam Nabi (Finance) 8. Ms. Huma Shakeel (Applied Statistics) 9. Ms. Wajiha Batool (Applied Statistics) 10. Ms. Maham Faheem (Applied Statistics)	(10)

11. Present Student Teacher Ratio in the Department

No. of M.Phil. Students: 34
No. of Permanent Faculty Members: 14

No. of Ph.D. Students: 22
No. of Permanent Faculty Members: 06

12. Course Outlines Separately for each course

M.PHIL. IN STATISTICS

COURSE OUTLINES

FOR

SEMESTER – I

Module Code:	STAT-501
Module Title:	Advanced Research Methods
Credit Hours:	3
Name of Scheme:	M.Phil. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- demonstrate the ability to identify and critically select appropriate literature to formulate and answer research questions/hypotheses, or contextualize research aims.
2- show autonomy and ability in designing a feasible and ethical research study that can appropriately address a given research question.
3- illustrate critical thinking through the ability to understand and evaluate the current literature and approaches.
4- identify the limits within methodological literature and designs.

Course Outlines

Preliminaries
Selection of research topic, sources of research literature, research material databases, using library and e-resources efficiently, finding literature, determining the authenticity of literature, literature review skills, literature review and plagiarism, HEC plagiarism policy, turnitin similarity report and plagiarism, citing styles, bibliography styles, using technology for literature review. Stating the objectives of study, selection of appropriate of methodology, novelty of work, presenting and defending the research topic.

Reviewing Literature
Reviewing and replication of relevant work, programming and statistical analysis, use of computer languages and softwares for analysis.

Research Write-Up
Synopsis writing, presentation of research work, presentation tools: Microsoft Powerpoint, LaTeX beamer. Thesis writing, components of thesis. Writing research articles, journals submission and reviewing process. Use of EndNote and LaTeX for writing scientific documents.

Recommended Books

1. Glenn, J. C., & Gordon, T. J. (2003). *Futures research methodology*. *Washington.*
2. Heck, A. (2002). *Learning LaTeX by doing*. AMSTEL Institute.
3. Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age International.
4. Kumar, R. (2018). *Research methodology: A step-by-step guide for beginners*. Sage.
5. Singh, Y. K. (2006). *Fundamental of research methodology and statistics*. New Age International.

Module Code:	STAT-504
Module Title:	Structural Equation Models
Credit Hours:	3
Name of Scheme:	M.Phil. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes:

By the end of this course, students should be able to:

1. understand the statistical theory on which SEM is based.
2. know when and how to apply SEM and how to interpret SEM results, but they also learn the pitfalls of SEM, and to question the application and results of SEM.
3. learn to read, understand, and interpret scientific articles in which SEM is applied.

Course Outlines

Preliminaries
Structural equation models' basics: Introduction, causation, types of variables, myths about sem.

Specification of Observed Variable (Path) Models
Steps of SEM, model diagram symbols, causal inference, specification concepts, path analysis models, recursive and non-recursive models, path models for longitudinal data.

Identification of Observed Variable (Path) Models
General requirements, unique estimates, rule for recursive models, identification of non-recursive models, models with feedback loops and all possible disturbance correlations, graphical rules for other types of non-recursive models, respecification of non-recursive models that are not identified, a healthy perspective on identification, empirical under identification, managing identification problems.

Estimation and Local Fit Testing
Types of estimators, causal effects in path analysis, single-equation methods, simultaneous methods, maximum likelihood estimation, fitting models to correlation matrices, alternative estimators. Goodness of fit indices. How to improve fit? Mediation and moderation analysis via SEM. SEM for categorical variables. Power analysis in SEM. Introduction of software (AMOS, STATA, LISREL, MPLUS, R, EQS etc.) used for SEM.

Recommended Books

1. Beaujean, A. A. (2014). *Latent variable modeling using R: A step-by-step guide.* Routledge.
2. Bollen, K. A. (2014). *Structural equations with latent variables*. Wiley-Interscience.
3. Byrne, B. M. (2016). *Structural equation modeling with AMOS: Basic concepts, applications, and programming*. Routledge - Taylor and Francis Group.
4. Hoyle, R. H. (2014). *Handbook of structural equation modeling*. The Guilford Press.
5. Kline, R. B. (2015). *Principles and practice of structural equation modeling*. The Guilford Press.
6. Schumacker, R.E., & Lomax, R.G. (2017). *A beginner's guide to structural equation modeling*. Lawrence Erlbaum Associates.

Module Code:	STAT-503
Module Title:	Machine Learning
Credit Hours:	3
Name of Scheme:	M.Phil. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning outcomes

By the end of the module, students should be able to:

1. develop an appreciation for what is involved in Learning models from data
2. understand a wide variety of machine learning algorithms
3. understand how to evaluate models generated from data
4. apply the algorithms to a real problem, optimize the models learned and report on the expected accuracy that can be achieved by applying the models

Course Outlines

Preliminaries
Introduction to machine learning. Machine learning and pattern recognition.

Supervised learning
Linear and non-linear regression, non-parametric methods, support vector machines and large-margin classifiers, kernel methods, model/feature selection methods.

Unsupervised learning
Clustering algorithms, K-means, expectation-maximization, Gaussian mixture models, anomaly detection, artificial neural networks. Reinforcement learning: Markov decision processes and ensemble learning: bagging, random forests, and boosting.

Recommended Books

1. Alpaydin, E. (2014). *Introduction to machine learning*. MIT press.
2. Marsland, S. (2011). *Machine learning: An algorithmic perspective*. Chapman and Hall/CRC.
3. Bishop, C. M. (2011). *Pattern recognition and machine learning*. Springer.

Module Code:	STAT-508
Module Title:	Advanced Multivariate Analysis
Credit Hours:	3
Name of Scheme:	M.Phil. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1. understand the concept of analyzing multivariate data.
2. appreciate the range of multivariate techniques available.
3. summarize and interpret multivariate data.
4. understand the link between multivariate techniques and corresponding univariate techniques.
5. appropriately undertake multivariate hypothesis tests, and draw appropriate conclusions.

Course Outlines

Matrix Algebra
Matrix theory and linear algebra.

Multivariate Distributions
Multivariate normal distribution, Wishart distribution, elliptical distributions.

Multivariate Linear Models
Growth curve model, multivariate regression analysis.

Methods of Multivariate Analysis
Principal component analysis, common factor analysis, multivariate analysis of variance, discriminant analysis, cluster analysis, canonical correlation analysis, and functional data analysis.

Recommended Books

1. Kollo, T., & Rosen, D.V. (2006). *Advanced multivariate statistics with matrices*. Springer.
2. Johnson, R. A., & Wichern, D. W. (2007). *Applied multivariate statistical analysis*. Pearson Prentice Hall.
3. Ramsay, J., & Silverman, B. W. (2005). *Functional data analysis*. Springer.
4. Rencher, A.C., & Christensen, W. F. (2012). *Methods of multivariate analysis*. Wiley.
5. Scott, D.W. (2015). *Multivariate density estimation*. Wiley.

M.PHIL. IN STATISTICS

COURSE OUTLINES

FOR

SEMESTER – II

Module Code:	STAT-502
Module Title:	Advanced Statistical Computing
Credit Hours:	3
Name of Scheme:	M.Phil. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- understand the general theories and computational procedures of the algorithms covered in the class.
2- write programs to implement the algorithms.
3- apply the methods to model real world data.

Course Outlines

Preliminaries
Downloading, installing and starting R and associate libraries. Calculating environment of R, types of R objects, vector, matrix, data frame, array etc. writing scripts, basic programming skills, logical statements, looping, programming flow and basic debugging, good programming habits, using built-in functions, input and output files, programming with functions, graphics.

Numerical Techniques
Finding roots, numerical integration and optimization. Probability and probability distributions, generating random numbers, selecting random samples, empirical study of the sampling distribution of estimators. Writing functions, designing empirical studies to verify the theoretical properties of various statistical methods.

Simulation and Bootstrapping
Simulation of data from a probability distribution, simulation of data for a regression model, simulation of data for time series model, Monte Carlo simulation, bootstrapping.

Recommended Books

1. Chen, D. G., & Chen, J. D. (2017). *Monte-Carlo simulation-based statistical modeling*. Springer.
2. Jones, O., Maillardet, R., & Robinson, A. (2009). *Introduction to scientific programming and simulation using R*. CRC Press, Taylor & Francis Group.
3. Maindonald, J., & Braun, J. (2006). *Data analysis and graphics using R: An example-based approach*. Cambridge University Press.
4. Pham, H. (2020). *Reliability and statistical computing*. Springer.
5. Voss, J. (2013). *An introduction to statistical computing: A simulation-based approach*. John Wiley & Sons.

Module Code:	STAT-506
Module Title:	Multilevel Models
Credit Hours:	3
Name of Scheme:	M.Phil. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes:

By the end of this course, students should be able to:

1. understand the principles and assumptions underlying multilevel.
2. estimate, confirm the validity of, and interpret such models using the statistical software.
3. apply multilevel models to a research problem according to a well-articulated research strategy.

Course Outlines

Preliminaries
Introduction to hierarchical structure data. Introduction to multilevel models: short review of regression, multilevel data structure, multilevel models, terminology and subscripts.

Two Levels Models
Random intercept, random slope, random intercept and random slope (univariate and multivariate), maximum likelihood estimation using Iterative Generalised Least Squares (IGLS), level-1 and level-2 residuals and assumption checking, group level coefficients, hypothesis testing and confidence intervals, robust (sandwich) estimators and jackknifing.

Multilevel Models for Discrete Response Data
Models for count data, binary logistic model, multinomial logistic model and ordinal logistic model. Three and higher levels multilevel models.

Recommended Books

1. Gelman, A., & Hill, J. (2007). *Data analysis using regression and multilevel/hierarchical models*. Cambridge University Press.
2. Goldstein, H. (2011). *Multilevel statistical models*. Halsted Press.
3. Jones, K., & Subramanian, S. V. (2015). *Multilevel statistical models: Concepts and applications*. Chan School of Public Health.
4. Kreft, I. G., & Leeuw, D. J. (1998). *Introducing multilevel modeling*. Sage.
5. Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*. Sage Publishers.
6. Snijders, T. A. B., & Bosker, R. J. (2012). *Multilevel analysis: An introduction to basic and advanced multilevel modeling.* Sage Publishers.

Module Code:	STAT-507
Module Title:	Metaheuristic Algorithms
Credit Hours:	3
Name of Scheme:	M.Phil. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes
On the completion of this course, the students will have the following outcomes defined in terms of knowledge, skill, and general competence:

Knowledge
The students have a basic understanding of how metaheuristics can be used to find good solutions for computationally hard optimization problems.

Skill

- The student will be able to implement a metaheuristic on a given problem.
- The student will explain for what type of problems metaheuristics can/should be used.

Course Outline

Preliminaries
Concepts of metaheuristics: Optimization models, optimization methods, representation, objective function, constraint handling, parameter tuning, performance analyses of metaheuristics. Random walk and levy flights.

Single Solution-Based Metaheuristics
Neighborhood, initial solution, fitness landscape analysis, local search. Population based metaheuristics: Initial population, stopping criteria. Differential evolution, ant and bee algorithms. Firefly algorithm, bat algorithm, cuckoo search.

Metaheuristics for Multi-Objective Optimization
Hybrid metaheuristics: Design issues, implementation issues. Combining metaheuristics with mathematical programming. Hybrid metaheuristics with machine learning and data mining. Hybrid metaheuristics for multi-objective optimization.

Recommended Books

1. Blum, C., Roli, A., & Sampels, M. (2008). *Hybrid metaheuristics: An emerging approach to optimization*. Springer.
2. Bozor, O., Solgi, M., Loaiciga, H. A. (2017). *Meta-heuristic and evolutionary algorithms for engineering optimization*. John Wiley & Sons, Inc.
3. Yang, X. S. (2010). *Nature-inspired metaheuristic algorithms*. Luniver press.

Module Code:	STAT-505
Module Title:	Spatial Statistics
Credit Hours:	3
Name of Scheme:	M.Phil. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1. distinguish different types of spatial data.
2. understand how spatial autocorrelation plays a role in statistical modelling.
3. determine which spatial methods to use in their own research and implement them using statistical software R.

Course Outlines

Preliminaries
Overview of spatial data; types of data, examples, projections; basics of point referenced data models, spatial processes, stationarity, variograms, spatial exploratory data analysis (EDA), kriging, basics of areal data models, EDA; Markov random fields, conditional autoregressive models.

Kriging

Spatial misalignment; multivariate spatial modelling; separable and coregionalization models, spatially varying coefficient models; spatial point patterns; dimension reduction approaches for large datasets. Advance kriging approaches; fixed rank kriging, predictive processes and multi-resolution kriging.

Bayesian Computation and Spatial Modelling

Brief review of Bayesian principles; prior specifications; hierarchical modelling, random effects. Importance sampling, Monte Carlo sampling and integration; Gibbs sampling and Markov Chain Monte Carlo (MCMC). Advance Bayesian computation – Approximate Bayesian Computation (ABC) methods and Integrated Nested Laplace Approximation (INLA).

Recommended Books

1. Blangiardo, M., & Cameletti, M. (2015). *Spatial and spatio-temporal Bayesian models with R-INLA*. John Wiley & Sons.
2. Cressie, N., & Wikle, C. K. (2015*). Statistics for spatio-temporal data*. Wiley.
3. Chiles, J. P., & Delfinder, P. (2012). *Geostatistics: Modeling spatial uncertainty*. Wiley.
4. Carlin, B. P., Gelfand, A. E., & Banerjee, S. (2014). *Hierarchical modeling and analysis for spatial data*. CRC Press.
5. Gamerman, D., & Lopes, H. F. (2006). *Markov chain Monte Carlo: Stochastic simulation for Bayesian inference*. CRC Press.
6. Gilks, W. R., Richardson, S., & Spiegelhalter, D. (1995). *Markov chain Monte Carlo in practice*. CRC Press.

PH.D. IN STATISTICS

COURSE OUTLINES

FOR

SEMESTER – I

Module Code:	STAT-501
Module Title:	Advanced Research Methods
Credit Hours:	3
Name of Scheme:	Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- demonstrate the ability to identify and critically select appropriate literature to formulate and answer research questions/hypotheses, or contextualize research aims.
2- show autonomy and ability in designing a feasible and ethical research study that can appropriately address a given research question.
3- illustrate critical thinking through the ability to understand and evaluate the current literature and approaches.
4- identify the limits within methodological literature and designs.

Course Outlines

Preliminaries
Selection of research topic, sources of research literature, research material databases, using library and e-resources efficiently, finding literature, determining the authenticity of literature, literature review skills, literature review and plagiarism, HEC plagiarism policy, turnitin similarity report and plagiarism, citing styles, bibliography styles, using technology for literature review. Stating the objectives of study, selection of appropriate of methodology, novelty of work, presenting and defending the research topic.

Reviewing Literature
Reviewing and replication of relevant work, programming and statistical analysis, use of computer languages and softwares for analysis.

Research Write-Up
Synopsis writing, presentation of research work, presentation tools: Microsoft Powerpoint, LaTeX beamer. Thesis writing, components of thesis. Writing research articles, journals submission and reviewing process. Use of EndNote and LaTeX for writing scientific documents.

Recommended Books

1. Glenn, J. C., & Gordon, T. J. (2003). *Futures research methodology*. *Washington.*
2. Heck, A. (2002). *Learning LaTeX by doing*. AMSTEL Institute.
3. Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age International.
4. Kumar, R. (2018). *Research methodology: A step-by-step guide for beginners*. Sage.
5. Singh, Y. K. (2006). *Fundamental of research methodology and statistics*. New Age International.

Module Code:	STAT-510
Module Title:	Optimization Techniques
Credit Hours:	3
Name of Scheme:	Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:

1. understand the complexities of, and techniques for obtaining optimal solution.
2. have enough knowledge and skills of advanced programming.
3. understand the theoretical framework underlying the techniques presented in class.
4. implement decision analysis to real life problems.
5. simulate any problem with the help of computer packages.

Course Outlines

Preliminaries
Definition of Operation Research (OR), nature and scope of operation research, objectives of OR, major phases of OR study, development of OR models and its application in various scenarios of business.

Optimal Solution
Feasible and optimal solutions, idea of simplex method, maximization and minimization case, big-m method, two-phase method or artificial variable method, duality problem, primal-dual relationships, optimal solution to dual problem, dual simplex method, sensitivity analysis.

Advanced Programming
Introduction to advance Linear Programming Model (LPM), properties of advance LPM, formulation of advance LPM, simplex method fundamentals, revised simplex method, boundary variables algorithms, duality, parametric linear programing. Introduction to non-linear programming, constraint, and unconstrained algorithms. Integer linear programing, its application and algorithms, deterministic dynamic programming, recursive nature of computation in DP, forward and backward recursion.

Transportation Models
Introduction to transportation model, comparison between LPM and transportation model, feasible solution by north-west corner method, least-cost cell method, Vogel's approximation method, least time model, sensitivity analysis of transportation model, assignment model.

Networking Models
Networking models, its definition and scope, various algorithm for the networking, maximum flow models, CPM and pert, Deterministic Inventory (DI) models. Development of DI models and its applications. Probabilistic inventory models and its application.

Decision Analysis
Introduction to decision analysis and games , classification of decisions, steps in decision theory approach, decision making under uncertainity, decision making under risk, criterion of optimism, criterion of pessimism, Hurwicz criterion, regret criterion, decision making with and without experimentation, Baye's decision rule, decision trees. Game theory and optimal solution of two person zero sum games, mixed strategy games.

Simulation
Introduction to simulation, advantages of simulation, types of simulation models, Monte Carlo simulation, generation of random numbers, use of computer packages and R programming for operation research study.

Recommended Books

1. Taha, H. A. (2007). *Operations research: An introduction.* Pearson Prentice Hall.
2. Hiller F. S., & Liberman, G. J. (2001). *Introduction to operations research*. McGrawHill.
3. Gupta, P. K., & Hira, D. S. (2015). *Operations research*. S. Chand Publications.
4. Murthy, P.R. (2007). *Operations research*. New Age International Publishers.

Module Code:	STAT-619
Module Title:	Advanced Multilevel Models
Credit Hours:	3
Name of Scheme:	Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:
1. master of advanced topics in MLM
2. have a deeper understanding of the relationship between MLM and GLM's.
3. conduct power analysis for virtually any multilevel design

Course Outlines
Estimation
The general structure and maximum likelihood estimation for a multilevel model, multilevel residuals estimation; shrunken estimates, delta method estimators for the covariance matrix of residuals. The EM algorithm. Partitioning the variance and intra-unit correlation. Maximum likelihood estimation with weights. Bootstrap estimation for multilevel generalised linear models, models for repeated measures data.

Fancy Multilevel Models
Nonlinear multilevel models. Multilevel event history and survival models. Measurement errors in multilevel models, smoothing models for multilevel data.

Recommended Books

1. Gelman, A., & Hill, J. (2007). *Data analysis using regression and multilevel/hierarchical models*. Cambridge University Press.
2. Goldstein, H. (2011). *Multilevel statistical models*. Halsted Press.
3. Jones, K., & Subramanian, S. V. (2015). *Multilevel statistical models: Concepts and applications*. Chan School of Public Health.
4. Kreft, I. G., & Leeuw, D. J. (1998). *Introducing multilevel modeling*. Sage.
5. Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*. Sage Publishers.
6. Snijders, T. A. B., & Bosker, R. J. (2012). *Multilevel analysis: An introduction to basic and advanced multilevel modeling.* Sage Publishers.

PH.D. IN STATISTICS

COURSE OUTLINES

FOR

SEMESTER – II

Module Code:	STAT-502
Module Title:	Advanced Statistical Computing
Credit Hours:	3
Name of Scheme:	Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- understand the general theories and computational procedures of the algorithms covered in the class.
2- write programs to implement the algorithms.
3- apply the methods to model real world data.

Course Outlines

Preliminaries
Downloading, installing and starting R and associate libraries. Calculating environment of R, types of R objects, vector, matrix, data frame, array etc. writing scripts, basic programming skills, logical statements, looping, programming flow and basic debugging, good programming habits, using built-in functions, input and output files, programming with functions, graphics.

Numerical Techniques
Finding roots, numerical integration and optimization. Probability and probability distributions, generating random numbers, selecting random samples, empirical study of the sampling distribution of estimators. Writing functions, designing empirical studies to verify the theoretical properties of various statistical methods.

Simulation and Bootstrapping
Simulation of data from a probability distribution, simulation of data for a regression model, simulation of data for time series model, Monte Carlo simulation, bootstrapping.

Recommended Books

1. Chen, D. G., & Chen, J. D.(2017). *Monte-Carlo simulation-based statistical modeling*. Springer.
2. Jones, O., Maillardet, R., & Robinson, A. (2009). *Introduction to scientific programming and simulation using R*. CRC Press, Taylor & Francis Group.
3. Maindonald, J., & Braun, J. (2006). *Data analysis and graphics using R: An example-based approach*. Cambridge University Press.
4. Pham, H. (2020). *Reliability and statistical computing*. Springer.
5. Voss, J. (2013). *An introduction to statistical computing: A simulation-based approach*. John Wiley & Sons.

Module Code:	STAT-511
Module Title:	Generalized Linear Models
Credit Hours:	3
Name of Scheme:	Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- communicate the role of generalized linear modelling techniques (GLMs) in modern applied statistics and implement methodology.
2- explain the underlying assumptions for GLMs and perform diagnostic checks whilst identifying potential problems.
3- perform statistical analysis using statistical software, incorporating underlying theory and methodologies.

Course Outlines

Preliminaries
Principles of statistical modelling, exponential family and generalized linear models, sampling distribution and inference based on score statistics, deviance and MLEs, Taylor series approximations, log-likelihood ratio statistic.

Logistic Regression
Binary variables and logistic regression, generalized linear models, dose response models, general logistic regression model, goodness-of-fit statistics and other diagnostics. Nominal and ordinal logistic regression.

Advanced Generalized Linear Models
Poisson regression, probability models for contingency tables and log-linear models, generalized linear mixed models, marginal models and generalized estimating equations.

Recommended Books

1. Dobson, A. J., & Barnett, A.G. (2008). *An introduction to generalized linear models*. Chapman and Hall/CRC.
2. Madsen, H., & Thyregod, P. (2010). *Introduction to general and generalized linear models*. Chapman and Hall/CRC.
3. Agresti, A. (2015). *Foundations of linear and generalized linear models*. Wiley.
4. Jiang, J. (2007). *Linear and generalized linear mixed models and their applications*. Springer.
5. McCullagh, P., & Nelder, J. A. (1989). *Generalized linear models*. Chapman and Hall/CRC.

Module Code:	STAT-512
Module Title:	Meta-Analysis
Credit Hours:	3
Name of Scheme:	Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1. to learn important aspects of a systematic review
2. to learn a systematic review of observational studies based on meta-analysis
3. to have an understanding of standard meta-analytic techniques and methodology.

Course Outlines

Preliminaries
What is meta-analysis? Why we need systematic reviews and meta-analyses?

Systematic Review Process and Plots
Diagnostic tests and accuracy, fixed and random effects in meta-analysis, differences in treatment effects in meta-analysis, forest plots, funnel plots.

Meta Regression and Reporting
Heterogeneity and meta-regression, power analysis for meta-analysis, meta-analysis methods based on p-values, publication bias, network meta-analysis and reporting a systematic review.

Recommended Books

1. Egger, M., Davey-Smith, G., & Altman, D. (2008). Systematic reviews in health care: Meta-analysis in context. John Wiley & Sons.
2. Julian, H., & Sally, G. (2008). *Cochrane handbook for systematic reviews of interventions*. John Wiley and Sons.
3. Michael, B., Larry, H., Julian, H., & Hannah, R. (2009). *Introduction to meta-analysis*. John Wiley and Sons.
4. Schwarzer, G., Carpenter, J. R., & Rücker, G. (2015). *Meta-analysis with R*. Springer.
5. Tom, P., & Jonathan, S. (2016). *Meta-analysis in Stata*. Stata Press.

Optional Courses

Module Code:	STAT-509
Module Title:	Advanced Statistical Methods in Quality Control
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:

1- understand the statistical methods for designing and realizing quality improvement activities.
2- handle experiments and propose appropriate solutions for process development and improvement.
3- implement fancier quality control approaches to handle complex real world data problems.

Course Outlines

Preliminaries
Concepts and definition of quality, Statistical Process Control (SPC) tools.

Multivariate Process Control
Hotelling's T^2 control chart, Failure-Mode and Effect Analysis (FMEA), Quality Function Deployment (QFD) - AKAO model, house of quality.

Experimental Design
Design of experiments, fractional factorial designs, robust designs. Taguchi experiments in industrial setups, mixture designs. Six sigma concept, define, measure, improve, control (DMAIC) philosophy. Design For Six Sigma (DFSS), quality standards - ISO 9000, ISO-14000, ISO 22000.

Recommended Books

1. Banks, J. (1989). *Principles of quality control*. John Wiley.
2. Feigenbaum, A. V. (2008). *Total quality control*. McGraw Hill.
3. Juran, J. M., & Guyana, F. K. (1988). *Juan's quality control handbook*. McGraw-Hill.
4. Miltag H. J., & Rinne, H. (1993). *Statistical methods of quality assurance*. Chapman & Hall.
5. Montgomery, D. C. (2013). *Introduction to statistical quality control*. McGraw Hill.
6. Verdeman, S.B., & Job, J.M. (2016). *Statistical methods for quality assurance: Basics, measurement, control, capability, and improvement.* Springer.

Module Code:	STAT-601
Module Title:	Linear Models and Applied Regression Analysis
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- develop a deeper understanding of the linear regression model and its limitations.
2- know how to diagnose and apply corrections to the handle violations of assumptions in the model.
3- develop a greater familiarity with a range of techniques and methods through a diverse set of theoretical and applied readings.

Course Outlines

Preliminaries
Linear algebra, linear regression models: Simple/multiple linear regression; likelihood estimators; geometrical intuition; weighted / generalized least squares estimators (LSE); properties of LSE; inference based on LSE; optimality of LSE; Gauss-Markov theorem.

Diagnostics and testing
Linearity; homoscedasticity; Gaussianity; independence; coefficient of determination; residuals; outliers; leverage points; hypothesis tests; ANOVA: one-way analysis of variance; orthogonality; F-tests, model selection: sequential (forward / backward / stepwise) model selection; information criteria (AIC/BIC/Cp); cross-validation.

Multicollinearity
Diagnostics for detection; ridge regression; LASSO, robust regression: L1 regression; trimmed least squares; M-estimators, non-linear regression: Newton-Raphson algorithm; nonlinear least squares, non-parametric regression: kernel smoothing; splines; projection-pursuit regression; additive models; backfitting algorithm.

Recommended Books

1. Christensen, R. (2011). *Plane answers to complex questions: The theory of linear models*. Springer.
2. Draper, N. R., & Smith, H. (2014). *Applied regression analysis*. Wiley.
3. Hastie, T. J., & Tibshirani, R. J. (1990). *Generalized additive models.* Chapman and Hall/CRC.
4. Kutner, M. H., Nachtsheim, C. J., & Neter, J. (2004). *Applied linear statistical models*. McGraw-Hill.
5. Seber, G. A. F., & Lee, A. J. (2014). *Linear regression analysis.* Wiley.

Module Code:	STAT-602
Module Title:	Probability Models and Applications
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- provide students with the knowledge of the theoretical aspects and modeling tools related to probability theory.

2- develop students' ability to apply the knowledge acquired during the course and to use probabilistic models in concrete situations, recognizing the appropriate frameworks and analytical tools related to the study.
3- apply probability models for multidimensional statistical analysis.

Course Outlines

Preliminaries
Preview of basic concepts: Probability, classical probability, axioms of probability, conditional probability and independent Markov Chains.

Random Variables
Random variables, distribution functions in one or more dimensions, expected value and moments, moments of random vectors, conditional moments, moment generating function, characteristic function and their application, inequalities of Markov, Chebyshev and Kolmogorov. Weak law of large numbers, strong law of large numbers, central limit theorem.

Probability Models
binomial distribution, multinomial distribution, geometric and negative binomial distribution, hypergeometric distribution, Poisson distribution, Poisson process, exponential and gamma distributions, beta distribution, normal distribution, bivariate normal, multivariate normal, lognormal distribution, Cauchy distribution, double exponential or Laplace distribution, Weibull distribution, Rayleigh distribution, logistic distribution, Pareto distribution, Pearsonian system of distributions.

Recommended Books
1. Athreya, K. B., & Lahiri, S. N. (2006). *Measure theory and probability theory*. Springer Science & Business Media.
2. Charalambides, C. A. (2005). *Combinatorial methods in discrete distributions*. John Wiley and Sons.
3. Feldman, R. M., & Valdez-Flores, C. (2009). *Applied probability and stochastic processes*. Springer Science and Business Media.
4. Mukhopadhyay, N. (2000). *Probability and statistical inference*. Marcel Dekker Inc.
5. Revuz, D. (2008). *Markov chains*. Elsevier.

Module Code:	STAT-603
Module Title:	Advanced Computer Applications
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- understand the basic set of commands and utilities in Linux/UNIX systems.
2- experience programming in Fortran, C/C++, Python.
3- learn mathematical calculations in Mathematica and MATLAB.

Course Outlines

UNIX/Linux Shell Scripting
Working with files and directories, file system permissions, shell programming, special characters and variables, creating menus, iteration/looping, subscripts and functions, advanced edit.

Python Programming
Python environment, flow controls, array types, working with files, functions, sorting, errors and exception handling, modules and packages, multithreaded and multi-process applications.

Computational Programming in Fortran and C/C++
Program creation, compilation and linking, variables and parameters, flow control, subroutines and functions. Structure and documentation. Use of libraries, internal and external communication, and interaction with other languages (e.g. R). Representation of data through arrays, pointers, and data structures. Function calls, argument passing and scoping rules, IO, profiling, system calls, and signals. Encapsulation and inheritance, polymorphic operators, and interaction with other languages (e.g. R).

Working with Mathematica and MATLAB
Numerical calculations, symbolic calculations, graphics, importing and exporting information. Polynomials, interpolation, integration, differentiation, and graphics.

Recommended Books

1. Attaway, S. (2018). *MATLAB: A practical introduction to programming and problem solving*. Elsevier.
2. Chollet, F. (2018). *Deep learning with Python*. Manning Publications.
3. Kerrisk, M. (2010). *The linux programming interface: A linux and unix system programming handbook*. No Starch Press.
4. Malik, D.S. (2018). *C++ programming: From problem analysis to program design*. Cengage Learning.
5. Metcalf, M., Reid, J., & Cohen, M. (2013). *Modern Fortran explained*. Oxford University Press.
6. Wellin, P. (2016). *Essentials of programming in Mathematica*. Cambridge University Press.

Module Code:	STAT-604
Module Title:	Sampling and Sampling Distributions
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- describe the idea of a sampling distribution and how it reflects the sample to sample variability of a sample statistic.
2- understand transformation of random variables and exact sampling distributions.
3- learn the relevant theory of extreme value statistics.

Course Outlines

Random Sampling
The sampling problem, random numbers in sampling practice, the technique of random sampling, random sampling numbers, Pseudo-random numbers, random values from specific distributions, sampling for attributes, standard error.

Standard Errors
Standard errors of moments, standard errors of functions of random variables, standard errors of bivariate moments. The Jackknife and bootstrap.

Transformation of Random Variables
Transformation of single random variable, transformation of several random variables, function of random variables. Sum, difference, product and ratio of two random variables. Transformation through characteristic functions.

Exact Sampling Distributions
Chi-square distribution, non-central Chi-square distribution, t-distribution, non-central t-distribution, F-distribution, Non-central F-distribution, Fisher's Z - distribution.

Extreme Value Statistics
Order statistics, evaluation of extreme values, type-I asymptotic distribution, type-II asymptotic distribution, type-III asymptotic distribution, estimation of extreme values from observed data.

Books Recommended
1. Athreya, K. B., & Lahiri, S. N. (2006). *Measure theory and probability theory*. Springer Science & Business Media.
2. Charalambides, C. A. (2005). *Combinatorial methods in discrete distributions*. John Wiley and Sons.
3. Feldman, R. M., & Valdez-Flores, C. (2009). *Applied probability and stochastic processes*. Springer Science and Business Media.
4. Mukhopadhyay, N. (2000). *Probability and statistical inference*. Marcel Dekker Inc.
5. Reiss, R. D. (2012). *Approximate distributions of order statistics: With applications to nonparametric statistics*. Springer science & business media.
6. Zolotarev, V. M. (2011). *Modern theory of summation of random variables*. Walter de Gruyter.

Module Code:	STAT-605
Module Title:	Measure Theory
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- understand basic concepts of measure and integration theory.
2- knowledge of measure theory needed to understand probability theory, statistics and functional analysis.
3- understand the concept of the Lebesgue measure.

Course Outlines

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 Minkowaski inequalities, convergence and completeness, bounded linear functional on L^p space Riesz representation theorem.

Recommended Books

1. Cohn, D. L. (2013). *Measure theory*. Birkhäuser.
2. Carlos, S.K. (2007). *Gulf professional publishing measure theory*. John Wiley and Sons.
3. Dipak, C.J. (2002). *Real analysis*. Prentice Hall.
4. Dudley, R. M. (2018). *Real analysis and probability*. CRC Press.
5. Gupta, S. L., & Gupta, N.R. (2003). *Principles of real analysis*. Pearson.
6. Malempati, M. R. (2004). *Measure theory and integration*. Marcel Dekker.

Module Code:	STAT-606
Module Title:	Bayesian Inference
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- describe the role of the posterior distribution, the likelihood function and the posterior distribution in Bayesian inference.
2- know how to work with loss functions.
3- understand the concepts of prior Monte Carlo methods of estimating posteriors.

Course Outlines

Preliminaries
Different types of prior and their uses, conditional independence, exchangeability.

Bayesian Inference and its Ingredients
Inference based on one parameter model (binomial and Poisson), inference based on two parameter model (normal), posterior predictive distributions.

Monte Carlo Methods
Posterior approximation with Gibbs sampler (GS), the Metropolis Algorithm (MA), Bayesian regression, generalized linear models, non-conjugate priors and implementation of the MA, hierarchical models.

Recommended Books

1. Gelman, A., Carlin, J. B., Stern, H. S., & Rubin, D. B. (2014). *Bayesian data analysis.* Chapman & Hall/CRC Press.
2. Carlin, B. P., & Louis, T. A. (2008). *Bayesian methods for data analysis*. Chapman & Hall / CRC Press.
3. Hoff, P.D. (2009). *A first course in Bayesian statistical methods*. Springer.
4. Albert, J. (2007). *Bayesian computation with R*. Springer.
5. Congdon, P. (2006). *Bayesian statistical modelling*. John Wiley and Sons.

Module Code:	STAT-607
Module Title:	Convergence in Probability
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1- understand the basics and properties of convergence.
2- learn convergence in probability distributions.
3- solve inequality problems in the context of probability distributions and convergence.

Course Outlines

Preliminaries
Weak convergence in metric spaces measure and integral. Tightness some examples. Properties of weak convergence. The Portmanteau theorem.

Other Criteria
The mapping theorem product spaces. Convergence in distributions, convergence in probability. Prohovov’s theorem, relative compactness. Tightness the proof.

The space C and Inequalities
Weak convergence and tightness in C. Wiener measure. Construction of Wiener measure. Donker’s theorem. An application. The Brownian bridge problems maximal inequalities. Maxmia of partial sums. A more general inequality. Some further inequality problems.

Recommended Books

1. Dupuis, P., & Ellis, R. S. (2011). *A weak convergence approach to the theory of large deviations*. John Wiley & Sons.
2. Kushner, H. (2012). *Weak convergence methods and singularly perturbed stochastic control and filtering problems*. Springer Science & Business Media.
3. Hall, P., & Heyle, C.C. (2014). *Martingale limit theory and its application*. Academic Press.
4. Resnick, S. (2019). *A probability path*. Springer.
5. Revuz, D., & Yor, M. (2013). *Continuous martingales and Brownian motion*. Springer Science & Business Media.

Module Code:	STAT-608
Module Title:	Statistical Inference
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students should be able to:

1. have vast knowledge about point estimation and properties of a good estimator.
2. learn key theorems of statistical inference especially in the context of their implementation.
3. get insights on hypothesis testing and confidence sets.

Course Outlines

Estimation
Criteria and methods for estimators, classical and newer methods of estimation, deriving estimators (Bayes method, MLE), Cramér–Rao and its extension, bias reduction by jackknifing, Rao-Blackwellization, Basr's theorem, estimation in parametric and non-parametric methods.

Interval Estimation
Two sided and one sided confidence intervals, C.I. For the mean, variance, proportion, difference, pivotal approach, ideas of accuracy measures, using C.I. in the tests of hypothesis, estimation of multivariate normal mean vector.

Hypothesis Testing
Basic concepts, UMP-tests, UMP unbiased tests, UMP invariant tests, SQRT, SP approx. SPRT in parametric and non-parametric models. Testing under nuisance parameters, review of tests for normal distribution.

Confidence Sets
Construction, properties, asymptotic confidence sets, bootstrap, confidence sets, simultaneous confidence intervals.

Recommended Books

1. Boos, D. D., & Stefanski, L. A. (2013). *Essential statistical inference*. Springer.
2. Efron, B., & Hastie, T. (2016). *Computer age statistical inference*. Cambridge University Press.
3. Hogg, R.V., & Craig, A. T. (1995). *Introduction to mathematical statistics*. Prentice-Hall International.
4. Mukhopadhyay, N. (2000). *Probability and statistical inference*. Marcel Dekker Inc.
5. Young, G. A., Young, G. A., Severini, T. A., Smith, R. L., & Smith, R. L. (2005). *Essentials of statistical inference*. Cambridge University Press.

Module Code:	STAT-609
Module Title:	Time Series Analysis
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:

1. get the key concepts of time series, its objectives, components and special features.
2. learn the descriptive techniques of transforming, differencing and analyzing the seasonal and irregular variations.
3. develop the probability models of time series along with their theoretical framework.

Course Outlines

Introduction
Objectives of time series analysis, Components of time series, time series plots, time series and stochastic processes, means and convergences.

Simple Descriptive Techniques
Stationary time series, transformations, analyzing the secular trend, filtering, differencing, analyzing seasonal variations, analyzing cyclical variations, analyzing irregular variations, auto-correlation (correlogram) and other tests of randomness.

Probability Models for Time Series
Stochastic processes and stationary processes, useful Stochastic processes, random process, moving average process, auto-regressive process. Mixed models, integrated models, general linear processes and continuous processes.

Models for Non-Stationary Series
Stationary through differencing: ARIMA models; other transformations.

Estimating the Auto-Covariance and Auto-Correlation Function
Fitting a moving average process and an auto-regressive process. Estimating the parameters of a mixed model and integrated model. The Box-Jenkins seasonal model. Model diagnostics: Residual analysis, over fitting and parameter redundancy.
Forecasting
Univariate procedures, multivariate procedures, comparison of forecasting procedures. prediction theory.

Recommended Books

1. Box, G. E., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2015). *Time series analysis: Forecasting and control*. John Wiley & Sons.
2. Chatfield, C. (1996). *The analysis of time series: An introduction*. Chapman & Hall/CRC.
3. Hamilton, J. D. (2020). *Time series analysis*. Princeton university press.
4. Lütkepohl, H. (2013). *Introduction to multiple time series analysis*. Springer Science & Business Media.
5. Percival, D. B., & Walden, A. T. (2000). *Wavelet methods for time series analysis*. Cambridge university press.

Module Code:	STAT-610
Module Title:	Stochastic Processes
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcome

On the completion of the course, students will have the following:

1. they will have basic knowledge about stochastic processes in the time domain.
2. the students will have more detailed knowledge about Markov processes with a discrete state space, including Markov chains, Poisson processes and birth and death processes.
3. the student will be able to formulate simple stochastic process models in the time domain and provide qualitative and quantitative analyses of such models.

Course Outlines

Preliminaries
Introduction to stochastic processes. Markov chains, transition and absolute probability, calculation of k-step transition probabilities. Chapman-Kolmogorov equations.

Classification of States and Chains
Classification of states. Classification of Markov chains. The ergodic property. The random walk. Gambler's ruin and expected duration of game.

Types of Stochastic Processes
Poisson process. Pure death process. Pure birth process. Renewal process. Branching process. The Wiener processes. Non-Markovian process. Stationary process. Queuing theory. Characteristics of queuing system. Simple queues. Multiple service channels. Optimization of queuing systems.

Books Recommended

1. Bailey, N. T. J. (1964). *The elements of stochastic processes with applications to natural science.* John Wiley and Sons.
2. Karlin, A. S. (1967). *A first course in stochastic processes.* Academic Press.
3. Srinivasan, S. K., & Mehata, K. M. (1988). *Stochastic processes*. Tata McGraw-Hill.
4. Yates, R. D., & Goodman, D. J. (1999). *Probability and stochastic processes*. John Willey & Sons.

Module Code:	STAT-611
Module Title:	Response Surfaces
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:

1- recognize how the response surface approach can be used for experiments where the factors are the components of a mixture.
2- recognize where the objective of the experiment is to minimize the variability transmitted into the response from uncontrollable factors.
3- understand the response surface methodology strategy to conduct experiments where system optimization is the objective.

Course Outlines

Preliminaries
Classical response surface methodology, building empirical models, matrix algebra, least squares, the analysis of variance and principles of experimental design.

Models and Designs
First order models and designs, second order models and designs, analysis of second-order response surfaces, methods of estimating response surfaces that rival least squares based on the Integrated mean squared error criterion.

Multiple Response Optimization
Analysis of multi response experiments, design of experiments for fitting response surfaces, response surface models with block effect, nonlinear response surface models, Taguchi's robust parametric design, robust parameter design and process robustness studies.

Recommended Books

1. Box, G. E., & Draper, N. R. (2007). *Response surfaces, mixtures, and ridge analyses*. Wiley.
2. Das, R. N. (2014). *Robust response surfaces, regression, and positive data analyses*. CRC Press.
3. Khuri, A. I., & Cornell, J. A. (2018). *Response surfaces: Designs and analyses*. Routledge.
4. Myers, R. H., Montgomery, D. C., & Anderson-Cook, C.M. (2016). *Response surface methodology*. Wiley.
5. Rodrigues, M. I., & Lemma. A. F. (2014). *Experimental design and process optimization*. CRC Press.

Module Code:	STAT-612
Module Title:	Biostatistics
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:

1- recognize and give examples of different types of data arising in public health and clinical studies.
2- understand and interpret relative risks and odds ratios when comparing populations.
3- learn why survival (timed to event) data requires its own type of analysis techniques.

Course Outlines

Preliminaries
Introduction to biostatistics, comparing group means under violation of standard assumptions (non-normality, heterogeneity of variances, non-independence), analysis of measurements' reliability, analysis of cross classified data; Chi-square distribution and its properties; measures of association (for cross-sectional, cohort and case-control studies); inference based on odds ratio.

Logistic Regression
Analysis of matched pairs, analysis of clustered binary data – testing homogeneity and inference based on the common odds ratio, measurement of inter clinician agreement for categorical data, statistical analysis of medical screening tests, logistic regression, logistic regression of clustered binary data and case-control studies.

Survival Data Analysis
Survival data analysis (parametric, non-parametric and semi parametric methods), non-parametric tests, non-parametric regression analysis.

Recommended Books

1. Collett, D. (2015). *Modelling survival data in medical research*. CRC press.
2. Daniel, W. W., & Cross, C. L. (2019). *Biostatistics: A foundation for analysis in the health sciences*. Wiley.
3. Indrayan, A., & Malhotra, R. (2018). *Medical biostatistics*. Chapman and Hall/CRC.
4. Pagano, M., & Gauvreau, K. (2018). *Principles of biostatistics*. Chapman and Hall/CRC.
5. Rosner, B. (2016). *Fundamentals of biostatistics*. Cengage Learning.

Module Code:	STAT-613
Module Title:	Advanced Bayesian Inference
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:

1- recognize Bayesian statistics and its theoretical links to decision theory.
2- understand the properties of Bayesian inference and their basic consequences and interpretations.
3- learn model's marginal likelihood and Bayes factors, posterior predictive model comparison and validation.

Course Outlines

Priors and Predictive Inference
Classical vs Bayesian statistics, statistical inference, Bayes' theorem; likelihood, prior distribution; posterior distribution; summaries of the univariate, bivariate & multivariate posterior distributions & applications. Posterior distributions using conjugate prior, predictive distribution; predictive inference, methods of elicitation of non-information priors.

Bayesian Testing of Hypothesis
Bayes factor for testing the sharp (point) hypothesis; the highest density region.

Bayesian Computations and Modelling
Bayesian computation, e.g. Gibbs sampling, Bayesian regression.

Recommended Books

1. Bernardo, J. M., & Smith, A. F. M. (2008). *Bayesian theory*. John Wiley and Sons.
2. Bolstad, W. M., & Curran, J. M. (2016). *Introduction to Bayesian statistics*. John Wiley & Sons.
3. Lee, P. M. (2004). *Bayesian statistics*. Oxford University Press.
4. Pawitan, Y. (2001). *In all likelihood: Statistical modelling and inference using likelihood*. Oxford University Press.
5. Sorensen, D., & Gianola, D. (2007). *Likelihood, Bayesian, and MCMC methods in quantitative genetics*. Springer Science & Business Media.

Module Code:	STAT-614
Module Title:	Repeated Measures Analysis
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:

1- recognize repeated measures designs and their basics.
2- carryout trend analysis and applications in repeated measure design.
3- explore and analyze multifactor experiments.

Course Outlines

Introduction
Basics of repeated measure designs, models and assumptions, variance–covariance structure, Box’s correction, Huynh-Feldt (HF) condition, circularity assumption, necessary and sufficient conditions for circularity, Mauchly's test of sphericity.
Trend Analysis and Applications
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.

Multifactor Experiments
Multi factor experiments in repeated measure designs, two factors experiment with one factor repeated measure, three factor experiments with repeated measure, controlling sequence effect, unequal group size, measures of association and statistical power in multifactor repeated measure designs.

Recommended Books

1. Hershberger, S. L., & Moskowitz, D. S. (2013). *Modeling intraindividual variability with repeated measures data: Methods and applications*. Psychology Press.
2. Islam, M.A., & Chowdhury, R.I. (2017). *Analysis of repeated measures data.* Springer Nature Singapore.

3. Montgomery, D. C. (2001). *Design and analysis of experiment*. John Wiley and Sons.
4. Verma, J. P. (2015). *Repeated measures design for empirical researchers*. John Wiley and Sons.
5. Weerahandi, S. (2004). *Generalized inference in repeated measures: Exact methods in MANOVA and mixed models*. John Wiley & Sons.

Module Code:	STAT-615
Module Title:	Decision Trees
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:
1- describe the input and output of a classification model.
2- tackle both binary and multiclass classification problems.
3- describe the underlying decision boundaries and build classification models for prediction.

Course Outlines

Classification
Meaning of classification, classifier and an overview of classification techniques, difference between supervised and un-supervised learning/classifiers.

Generation Procedures
Decision trees and their generation procedures (tree growing process), role of evaluation functions to split parent node into two sub-nodes, various node splitting evaluation functions (impurity-based and non-impurity-based) including Gini index, towing rule and entropy function.

Construction and Evaluation
Properties of impurity-based evaluation functions, selection criterion to split a node, estimation of error rates and right sized classification trees. Construction of classification trees; evaluating the performance of a classifier: holdout method, random sub-sampling, cross-validation and bootstrap samples.

Recommended Books

1. Andrew, R. W. (2002). *Statistical pattern recognition*. John Willey & Sons.
2. Bramer, M. (2007). *Principles of data mining*. Springer-Verlag.
3. Rao, C. R., Wegman, E. J., & Solka, J. L. (2005). *Handbook of statistics*: Data mining and data visualization. Elsevier.
4. Rokach, L., & Maimon, O. Z. (2008). *Data mining with decision trees: Theory and applications*. World Scientific.
5. Tan, P., Steinbach, M., & Kumar, V. (2006). *Introduction to data mining*. Addison Wesley.

Module Code:	STAT-616
Module Title:	Big Data Analysis
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

At the end of this course, students will have the following:

1. basic knowledge of big data analytics techniques and tools.
2. implementation of big data techniques to a variety of domains such as business, finance/banking industry, and health care.

Course Outlines

Preliminaries
Overview of unsupervised and supervised learning, high dimensional big data and pattern analytics: Dimensionality reduction (UV, SVD, and CUR decompositions); independent component analysis (ICA) for pattern separation and identification.

Algorithms
Algorithms for very-large-scale mining; clustering; nearest-neighbor search, large-scale machine learning; gradient descent; support-vector machines; classification and regression.

Computing
Parallel computing; distributed and parallel algorithms, cloud storage and computing, introduction to Linux.

Recommended Books

1. Kontoghiorghes, E. J. (2005). *Handbook of parallel computing and statistics.* Chapman and Hall/CRC.
2. Thisted, R. A. (1988). *Elements of statistical computing: Numerical computation*. Chapman and Hall/CRC.
3. Gentle, J. E., Härdle, W. K., & Mori, Y. (2012). *Handbook of computational statistics: Concepts and methods*. Springer.
4. Friedman, J., Hastie, T., & Tibshirani, R. (2001). *The elements of statistical learning*. Springer.
5. Kutz, J. N. (2013). *Data-driven modeling & scientific computation*. Oxford University Press.

Module Code:	STAT-617
Module Title:	Advanced Sampling Techniques
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:

1- review key sampling concepts required to understand fancier sampling ideas.
2- understand and implement more formal sampling estimators.
3- describe the design and model based sampling inference to handle complex real life data applications.

Course Outlines

Background
Introduction to Statistics, introduction to survey sampling, simple random sampling, ratio and regression estimators, sampling with probability proportional to size, selection with unequal probabilities with replacement.

Formal Estimators
The Horvitz–Thompson estimators, some selection procedures associated with the Horvitz–Thompson estimator, Rao, Hartley, Cochran method.

Sampling Inference
The design and model based sampling inference (P), the stratified random sampling (P), reasons for cluster sampling. Variance in terms of intra-cluster correlation (P), sampling with probability proportional to size, selection with unequal probabilities with replacement, relative accuracies of three techniques (P), methods related to systematic sampling (P).

Recommended Books

1. Brewer, K. R. W., & Hanif, M. (1983). *Sampling with unequal probabilities: Lecture notes in Statistics series.* Springer.
2. Cochran, W.G. (1977). *Sampling techniques*. John Wiley and Sons.
3. Esbensen, K.H. (2020). *Introduction to the theory and practice of sampling*. IM Publications Open.
4. Hansen, M. H., Hurwitz, W.N., & Madow, W. G. (1993). *Sampling survey methods and theory*. John Wiley & Sons.
5. Kish, L. (1995). *Survey sampling*. John Wiley and Sons.
6. Thompson, S.K. (2012). *Sampling*. John Wiley and Sons.

Module Code:	STAT-618
Module Title:	Applied Smoothing Techniques
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:

1- understand a general class of techniques for nonparametric estimation of functions and kernel smoothing.
2- handle major problems for kernel smoothing e.g. the selection of the bandwidth which controls the amount of smoothing.

3- implement fancier smoothing approaches to handle complex real world data problems.

Course Outlines

Preliminaries
Basic concepts of smoothing techniques. Univariate kernel density estimator, the MSE and MISE criteria. Order and asymptotic notation, Taylor expansion. Asymptotic MSE and MISE approximates, exact MISE calculations.

Kernel Estimators
Canonical kernels and optimal kernel theory, higher-order kernels. Local kernel density estimator, variable kernel density estimator. Density derivation estimation, bandwidth selection. Quick and simple bandwidth selectors, least square cross-validation and biased cross-validation. Plug-in bandwidth selection. Smoothed cross-validation bandwidth selection.

More Formal Techniques
Multivariate kernel density estimator and asymptotic MISE approximations. Bandwidth selection. Local polynomial kernel estimators, asymptotic MSE approximation: linear case. Local polynomial kernel estimators. Multivariate non-parametric regression.

Recommended Books

1. Fan, J., & Gijbels, I. (2013). *Local polynomial modeling and its applications: Monographs on Statistics and applied probability*. CRC Press.
2. Härdle, W. (2011). *Applied nonparametric regression*. Cambridge University Press.
3. Scott, D. W. (2015). *Multivariate density estimation: Theory, practice and visualization*. John Wiley and Sons.
4. Schimek, M. G. (2012). *Smoothing and regression: Approaches, computation and application*. Wiley.
5. Simonoff, J. S. (2010). *Smoothing methods in statistics*. Springer.
6. Wand, M. P., & Jones, M. C. (2012). *Kernel smoothing*. Chapman and Hall.

Module Code:	STAT-620
Module Title:	Mathematical Methods for Statistics
Credit Hours:	3
Name of Scheme:	M.Phil. / Ph.D. in Statistics
College:	College of Statistical and Actuarial Sciences
Faculty:	Science

Learning Outcomes

By the end of this course, students will be able to:

1- have insights into the mathematical, statistical, and computational basis of analyses.
2- understand the mathematical tools that are needed to solve optimization problems
3- do research in the field of mathematical statistics.

Course Outlines

Background
Real numbers, point set theory, limit points, limits, sequences and series, Taylor series (multivariate), uniform convergence, Riemann-Stieltjes integrals.

Computational Mathematics
Stochastic partial differential equations, computational geometry, wavelet analysis and integration theory.

Optimization
Linear and non-linear optimization, convex analysis and simulation based optimization.

Recommended Books

1. Abbott, S. (2001). *Understanding analysis*. Springer.
2. Hijab, O. (2007). *Introduction to calculus and classical analysis*. Springer.
3. Giaquinta, M. & Modica, G. (2007). *Mathematical analysis: Linear and metric structures and continuity*. Birkhäuser Boston.
4. Robdera, M. A. (2011). *A concise approach to mathematical analysis*. Springer.
5. Ponnusamy, S. (2011). *Foundations of mathematical analysis.* Birkhäuser Boston.
6. Pugh, C. C. (2015). *Real mathematical analysis*. Springer.