MPhil Courses		
Course Code	Course Title	Credit Hours
STA-701*	Multivariate Analysis*	3(3-0)
STA-702	Probability Distributions	3(3-0)
STA-703	Advanced Design of Experiments	3(3-0)
STA-704	Linear Models and Regression Analysis	3(3-0)
STA-705	Research Methods	3(3-0)
STA-706	Optimization Techniques	3(3-0)
STA-707	Bayesian Analysis	3(3-0)
STA-708*	Statistical Inference*	3(3-0)
STA-709	Categorical Data Analysis	3(3-0)
STA-710	Survival Data Analysis	3(3-0)
STA-711	Time Series and Forecasting	3(3-0)
STA-712	Biostatistics	3(3-0)
STA-713	Population Analysis and Official Statistics	3(3-0)
STA-714	Non-Parametric and Robust Methods	3(3-0)
STA-715	Advanced Statistical Process Control	3(3-0)

*Core courses compulsory to qualify for MPhil degree

Detailed Course outline for Courses that can be taken during MPHIL (Statistics) Program

STA-701   Multivariate Analysis   3(3-0)

Introduction to multivariate data analysis and matrix algebra, Multivariate Normal Distribution, Wishart distribution and their properties. Hotelling's T2–Distribution. Methods of Estimation; Maximum Likelihood and least squares. Multivariate Analysis of variance (MANOVA), Multivariate Hypothesis testing. Likelihood ratio test. One sample and multi-sample hypothesis. Principal Component Analysis, Factor Analysis, Discriminant Analysis. Canonical Correlation. Cluster analysis, Path analysis.

Recommended Books
- Schumacker, R. E. (2015). Using R with Multivariate Statistics. Sage Publications.
- Johnson, R.A., and Winchern, D.W. (2007). Applied Multivariate Statistical Analysis. Prentice Hall. London.

- Anderson, T.W. (2003). An Introduction to Multivariate Statistical Analysis, Wiley, New York.
- Sharma, S. (1995). Applied Multivariate Techniques, Wiley, New York.
- Chatfield, C. and Collins, A. J. (1981). Introduction to Multivariate Analysis, Chapman and Hall, London.
- Mardia, K.V., Kent, J.T., and Bibby, J. M. (1979). Multivariate Analysis, Academic Press, London.

STA-702   Probability Distributions   3(3-0)

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 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, Central Limit Theorem. Some families of Distributions: Pearson, Johnson, and Burr families. Characteristics functions of Distributions. Independence of mean vector and the quadratic form of normal variables.

Recommended Books

- Dall'Aglio, G., Kotz, S., and Salinetti, G (2012). Advances in Probability Distributions with given Marginals: beyond the copulas. Springer Science & Business Media.
- Ross, S. M. (2005). A First Course in Probability. Prentice Hall.
- Kotz, S., Balakrishnan, N. and Johnson, N. L. (2000). Continuous multivariate distributions – Volume 1, Models and Applications, 2nd Edition, Wiley, New York.
- Ross, S. M. (2002). Introduction to Probability Models. 8th Edition", Academic Press.

STA-703   Advanced Design of Experiments   3(3-0)

Popular screening designs, A brief review of Factorial experiments: 2k, Plackett-Buman designs, irregular factorial designs, 3k series and mixed level factorial experiments and their analyses. Confounding in factorial experiments: complete and partial confounding. Confounding in factorial replications. Estimation of effects: Yate's algorithm, contrast method. Design resolution. Minimum aberration designs. Fold-over design; Incomplete block designs, Lattice designs, generalized lattice designs, particularly

balance incomplete block designs, PBIBD with recovery of intra-block information, Youden square designs, change-over trials.

Recommended Books

- Montgomery, D.C. (2012). Design and Analysis of Experiments, 8th Ed. Wiley, New York.
- Xu, H. (2006). Design and analysis of experiments, volume 2: Advanced experimental design. *Technometrics*, *48*(4), 571.
- Jones, B. and Kenward, M.G. (2003), Design and Analysis of Cross-over Trails. Chapman and Hall, London.
- Clarke, G.M., and Kempton, R.E. (1997), Introduction to the Design & Analysis of Experiments, Edward Arnold.
- Cochran, W.G. and Cox, G.M. (1992), Experimental Design, Wiley, New York.
- Harold, R.L (1992) Analysis of Variance in Experimental Design. Springer Verlag.
- Das, M.N. and Giri, N.C. (1986). Design and Analysis of Experiments, Wiley, New York.

STA-704   Linear Models and Regression Analysis   3(3-0)

Linear Models: Definition, forms, functionally related models, mean related models, Matrix approach to linear regression. Examination of Residuals: Residual plots, Correlation among the residuals and its test. Generalized linear Models and Polynomial Models: Models involving non-integral transformation, Families of transformation, Orthogonal Norms, Projections. Selecting the best Regression. Least Square and Unbiased Estimation, BLUE, Marginal distribution and linear function of Normal Variables.

Multiple Regression Models: Introduction and applied to ANOVA. Heteroscedasticity, Multicollinearity, Ridge Regression, Robust Regression, Outlier Diagnostics, Jack Knifing, Boot strapping and analysis of incomplete data. Point Estimation, Interval estimation, Simultaneous confidence Interval, Testing of hypothesis.

Recommended Books

- Dobson, A. J., & Barnett, A. G. (2018). *An introduction to generalized linear models*. 4th Edition. CRC press.
- Hardin, J. W. & Hilbe, J.M. (2018). *Generalized linear models and extensions*. 4th Edition Stata press.
- Hill, R. C., Griffiths, W. E., & Lim, G. C. (2018). *Principles of econometrics*. John Wiley & Sons.
- Verbeek, M. (2017). A guide to modern econometrics, Fifth Edit. ed. John Wiley & Sons.
- Greene, W. H. (2016). *Econometrics*. Prentice Hall.

- Gujarati, D. (2014). Econometrics by Example, Red Globe Press.
- Draper, N.R. and Smith, H. (2004). Applied Regression Analysis. Wiley, New York.
- Harrell, F.E. (2003). Regression Modeling Strategies. Springer Texts in Statistics.
- Christensen, J. (2002). Advanced Linear Modeling. Springer Texts in Statistics

STA-705   Research Methods   3(3-0)

Science and Research: Steps of Research process, Research Process, Research Proposal. Theory and Research, Research Design: Design Strategies, Measurement, Scaling Design, Measures of Emotions Derived attitude scales, Observational and Physiological Measures. Sampling Design (Probability Sampling, Complex Probability Sampling, Systematic sampling, Stratified sampling, Cluster sampling, Double and Multistage sampling, Non-probability sampling techniques). Sample size determination, Random Numbers, Sampling frames, Non-response. Methodology and Literature Review.

Sources of research data: Secondary data sources, Survey Methods, Instruments for respondent communication (Questionnaire Design, etc.), Observational studies, Experimentation, Historical comparative Research. Analysis & Presentation of Data: Data Preparation and Preliminary Analysis, Estimation, Hypothesis testing; Univariate and Multivariate tests, Measures of Association, Multivariate Analysis: An overview, Forecasting. Presenting Results: Written and Oral Reports.

Recommended Books
- Tracy, S. J. (2019). Qualitative research methods: Collecting evidence, crafting analysis, communicating impact. John Wiley & Sons.
- Devi, P. S. (2017). Research methodology: a handbook for beginners. Notion Press.
- Walliman, N. (2017). Research methods: The basics. Routledge.
- Stokes, P., & Wall, T. (2014). Research methods. London: Palgrave.
- Mutch, C. (2013). Doing educational research. Nzcer Press.
- Yin, Robert, K. (2009). Case Study Research: Design and Methods. 4th Edition, Sage Publications, London.
- Shank, G. D. (2006). Qualitative research: A personal skills approach. Upper Saddle River, NJ: Pearson Merrill Prentice Hall.
- Cooper, D. R., Schindler, P. S., & Sun, J. (2003). Business research methods.
- Miller, D. C., & Salkind, N. J. (2002). Handbook of research design and social measurement. Sage.
- Robinson, G.K. (2000). Practical Strategies for experimenting. Wiley, New York.

STA-706   Optimization Techniques   3(3-0)

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.

Recommended Books
- Sinha, G. R. (2019). Modern Optimization methods for science, Engineering and Technology. IOP Publishing Inc., USA.
- Kochenderfer, M. J. and Wheeler, T. A. (2018). Algorithms for Optimization. MIT Press USA.
- Gass, S.I. (2003). Linear Programming: Methods and Applications. 5th Edition, Dover publications Inc., Mineola, New York.
- Taha, H.A.(1992) Operations Research 5th ed. (Macmillan)

STA-707   Bayesian Analysis   3(3-0)

Bayes' theorem; likelihood, Informative and non-informative prior distributions; Posterior distribution; Summaries of the univariate, bivariate & multivariate posterior distributions & applications. Posterior distributions using conjugate prior. Prior predictive and posterior predictive distributions; Predictive inference. Methods of elicitation of non-information priors. Bayesian hypothesis testing; Bayes factor for testing the sharp (point) hypothesis; Highest density region. Bayesian computation, e.g. Monte Carlo simulation and Gibbs sampling.

Books Recommended
- Turkman, M. A. A., Paulino, C. D., & Müller, P. (2019). Computational Bayesian Statistics: An Introduction (Vol. 11). Cambridge University Press.

- Berger, J. O. (2013). Statistical decision theory and Bayesian analysis. Springer Science & Business Media.
- Bolstad, W.M. (2007). Introduction to Bayesian Statistics. 2nd Edition, Wiley, New York.
- DeGroot, M. H. (2004). Optimal Statistical Decisions. Wiley, New York.
- Carlin, B.P. and Louis, T.A. (2000). Bayes and Empirical Bayes Methods for Data Analysis. 2nd Edition, Chapman and Hall, London.
- Lee, P. M. (1991). Bayesian Statistics: An Introduction. Oxford University Press, New York.

STA-708   Statistical Inference   3(3-0)

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, unbiasedness, consistency of estimators, consistency of the estimator of variance. asymptotic normality of estimators of unknown parameters and their variances, 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, Bayes estimation, computing posterior distributions, loss function, risk function, decision function, Bayes estimators, admissibility, minimax estimators. Introduction of hypothesis testing, Neyman Pearson lemma, monotone-likelihood ratio approach, exponential class of densities, hypothesis testing methods, generalized likelihood ratio tests, sequential probability ratio test, asymptotic properties of generalized likelihood ratio test, lagrange's multiplier tests, wald test, unbiased test, consistent 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.

Recommended Books

- Hacking, I. (2016). Logic of Statistical Inference. Cambridge University Press
- Rohatgi, V. K., & Saleh, A. M. E. (2015). An introduction to probability and statistics. John Wiley & Sons.

- Robert B. (2013). Statistical Inference: A Concise Course. Published by Courier Corporation
- Rajagopalan, M, & Dhanavanthan, P. (2012). Statistical Inference. PHI Learning Pvt. Ltd.
- Garthwaite, P., Jolliffe, I. and Jones, B. (2002). Statistical Inference. OXFORD University Press.
- Mood, A.M. Graybill, F.A. and Boss, D.C. (1997). Introduction to the Theory of Statistics. McGraw Hill, New York .
- Lehmann, E.L. (1997). Testing Statistical Hypotheses. Springler - Valag, New York.
- Lehman, E.L. (1983). Theory of Point Estimation. Wiley, New York.
- Rohatgi, V.K. (1984). Statistical Inference. Wiley, New York.

STA-709   Categorical Data Analysis   3(3-0)

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

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

Poisson regression model, Poisson regression for rates, Log-linear models for contingency tables, Negative binomial models, Quasi-likelihood and Generalized Estimating Equations, Generalized linear mixed models.

<u>Recommended Books</u>
- McCullagh, P. (2018). Generalized linear models. Routledge.
- Rudas, T. (2018). Lectures on categorical data analysis. Springer.
- Agresti, A. (2013). Categorical Data Analysis. John Wiley & Sons.
- Andersen, E. B. (2012). The statistical analysis of categorical data. Springer Science & Business Media.Hosmer, D. W. and Lemeshow, S. (2004). Applied Logistic Regression. Wiley, New York.
- Agresti, A. (2010). Analysis of ordinal categorical data, 2nd Edition. Wiley, New York.
- Simonoff, J. S. (2003). Analyzing Categorical Data. Springer.

STA-710   Survival Data Analysis   3(3-0)

Multi-parameter analysis using large sample likelihood methods for response time data, survival function and hazard function, multi-parameter models, re-parameterization 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.

Recommended Books
- Klein, J. P., Van Houwelingen, H. C., Ibrahim, J. G., & Scheike, T. H. (Eds.). (2016). Handbook of survival analysis. CRC Press.
- Lee, E.T. and Wang, J.W. (2013). Statistical Methods for Survival Data Analysis, 4th Edition. Wiley, New York.
- Liu, X. (2012). Survival Analysis: Models and Applications. Wiley, New York.
- Hosmer, D.W., Jr., Lemeshow, S. and May, S. (2008). Applied Survival Analysis: Regression Modeling of Time to Event Data, 2nd Edition. Wiley, New York.
- Huber, C., Limnios, N., Mesbah, N. and Nikulin, M. (2008). Mathematical Methods in Survival Analysis, Reliability and Quality of Life, Wiley, New York.

STA-711   Time Series and Forecasting   3(3-0)

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
- Mills, T. C. (2019). Applied Time Series Analysis: A Practical Guide to Modeling and Forecasting. Academic Press.
- Hyndman, R. J., & Athanasopoulos, G. (2018). Forecasting: principles and practice. OTexts.
- Agung, I. G. N. (2011). Time series data analysis using EViews. John Wiley & Sons.
- Shumway, R. H. and Stoffer, D. S. (2010). Time series analysis and its applications with R examples, 3rd Edition. Springer.

- Cryer, J. D. and Chan, K. S. (2008). Time series analysis with applications in R, 2nd edition.
- Palit, A. K., & Popovic, D. (2006). Computational intelligence in time series forecasting: theory and engineering applications. Springer Science & Business Media.
- Box, G. E. P. and Jenkins, G.M (1999). Time series analysis: forecasting and control. San Francisco.
- Chatfield, C. (1996). The analysis of time series: an introduction. Chapman and Hall, London.
- Cox, D. R., Hinckley D.V. and Nielsen O. E. B. (1996). Time series models in econometrics, finance and other fields. Chapman and Hall London.
- Harvey, A. C. (1990). Forecasting structual time series models and the calamander. Cambridge university press, cambrige.

STA-712　　　　　　Biostatistics　　　　　3(3-0)

Comparing group means when the standard assumptions are violated; Non-normality, Heterogeneity of variances, Non-independence. Analysis of measurements reliability: Models for reliability studies, comparing precisions of two methods, concordance correlation, Assessing reproducibility using the coefficient of variations. Analysis of cross-classified data: Chi-Square distribution and its properties, Measures of association (cross-sectional studies; cohort and case-control studies), Inference on odds ratio, significance tests and interval estimation, analysis of several 2x2 contingency tables. Analysis of matched pairs (one case and one control) estimating odds ratio, Analysis of clustered binary data – testing homogeneity and inference on the common odds ratio. Measurement of inter clinician agreement for categorical data, Statistical analysis of medical screening tests. Simple regression and logistic Regression: logistic transformation, coding and interpreting coefficients interaction and confounding, Model comparisons, Logistic regression of clustered binary data and case-control studies.

Survival Data Analysis: Non-parametric methods, parametric methods, semi-parametric methods. Distribution–free Statistics: Sign test, Wilcoxon signed – rank test for location, The Median test, The Mann-Whitney U-test, The Kolmogorov-Smirnov goodness of fit test, The Kruskal-Wallis one way analysis of variance test, The Friedman two-way analysis of variance, Spearman rank correlation, Non-parametric regression analysis.

Recommended Books
- Daniel, W.W. (2018). Bio-statistics: A foundation for analysis in the health sciences, 11th Edition. Wiley, New York.

- Chow, S.C. and Liu, J.P. (2013). Design and Analysis of Clinical Trials: Concepts and Methodologies. 3rd Edition. Wiley, New York.
- Rosner, B.A. (2016). Fundamentals of Biostatistics, 8th Edition. Thomson Books.
- Belle, G.V., Fisher, L.D., Heagerty, P.J. and Lumley, T. (2004). Biostatistics- A Methodology for the Health Sciences, 2nd Edition. Wiley, New York.
- Chernick, M.R. and Friis, H.R. (2003). Introductory Biostatistics for Health Sciences- Modern Application Including Bootstrap. Wiley, New York.
- Michelson, S. and Schofield, T. (2002). The Biostatistics Cookbook. Kluwer Academic Publishers.

STA-713   Population Analysis and Official Statistics   3(3-0)

Population and Demographic Methods, Sources of Demographic data, Testing of accuracy of demographic data, Basic demographic measures, Life tables, Population estimates and projections, Application of Stationary Population Models. Official Statistics: Statistical Systems in Pakistan, Statistics Divisions and Bureaus of Statistics: their functioning and publications. National Accounts: measures of production, income and expenditure, the national income and product, Gross Domestic product, saving and wealth, Index Numbers Social Indicators.

Recommended Books
- Caselli, G., Vallin, J., & Wunsch, G. (2005). *Demography: Analysis and Synthesis, Four Volume Set: A Treatise in Population*. Elsevier.
- Bowling, A., & Ebrahim, S. (2005). *Handbook of health research methods: investigation, measurement and analysis*. McGraw-Hill Education (UK).
- Preston, S.H., Heuveline, P. and Guillot, M. (2001). Demography: Measuring and Modeling Population Processes. Malden, Massachusetts: Blackwell Publishers Inc.
- Levitas, R., & Guy, W. (Eds.). (1996). *Interpreting official statistics*. Psychology Press.
- Abel, A.B. and Bermake, B.S. (1995). Macroeconomic. Addison-Wesly Publishing Company, New York
- Pollard, A.H., Yusuf, F. and Pollard, G.N. (1995). Demographic Techniques, 4th Edition. Pergaman Press.
- Publications of Statistics Division I, State Bank of Pakistan, Provisional Bureaus of Statistics and other departments.

STA–714   Non-Parametric and Robust Methods   3 (3–0)

Common non-parametric tests, Non-parametric analysis of variance, Non-parametric regression, the concept of robustness in different fields and applications, breakdown and

the influence curve, estimation using M, L and R Statistics, Contaminated distributions, Sampling-resampling Methods: Bootstrap and Jackknife. Confidence Intervals.

Recommended Books
- Gibbons, J. D. and Chakrabortic, S., Nonparametric Statistical Inference, Marcel Dekker, New York (2014).
- Huber, P., Robust Statistical Procedures, Society for Industrial and Applied Mathematics, (1987).
- Maritz, J. S., Distribution Free Statistical Methods, Chapman and Hall, London, (1995).
- Rousseeuw, L., Robust Regression and Outlier Detection, John Wiley and Sons, (1987).
- Conover, W. J., Practical Nonparametric Statistics, 3rd Ed., John Wiley and Sons. New York, (1999).

STA-715   Advanced Statistical Process Control   3 (3-0)

Dimensions of quality control, total quality managements, statistical process control and its tools, Memoryless and Memory type control charts in univariate and multivariate set up, Process capability study, Control charts with different samplings schemes and their effects on the performance of control charts, Mixed control charts, Combined control charts, Non-parametric and robust control charts, Enhanced control charts with auxiliary information and using different run rules schemes, Process capability analysis, Acceptance sampling plans, Some Bayesian structures for quality control, Designed experiment and process monitoring, Role of Monte Carlo Simulation in control charts.

Books Recommended

1. Montgomery, D.C. (2009). *Introduction to Statistical Quality Control*. 5th edn. John Wiley & Sons.

2. Oakland, J.S. (2007). *Statistical Process Control*. 6th edn. Butterworth-Heinemann, Elsevier Science Publisher.

3. Alwan, L.C. (2000). *Statistical Process Analysis.* McGraw-Hill.

4. Farnum N.R. (1994). *Statistical Quality Control and Improvement*. Duxbury.

5. Quesenberry, C.P. (1997). *SPC Methods for Quality Improvement*. John Wiley and Sons.

6. Wheeler, D.J. (1995). *Advance Topics in Statistical Process Control- the Power of*

Shewhart's Charts. SPC Press, Knoxville.

7.   Ryan, T.P. (1989). *Statistically Methods for Quality Improvement*. John Wiley and Sons.