Institute of Statistical Research and Training
University of Dhaka

Syllabus

M.S. Program in Applied Statistics
Session : 2016–2017

www.isrt.ac.bd/syllabus

M.S. Program in Applied Statistics

The Master of Science (M.S.) program in Applied Statistics is a one academic year program. The minimum requirement for the admission to this program is the successful completion of the B.S. Honours degree in Applied Statistics. The regulations for the admission and the examinations will be the same as those of the M.S. courses in the Faculty of Science unless otherwise stated. There are two types of course designs available for the M.S. program in Applied Statistics:

Group A	:	M.S. degree based only on course work.
Group B	:	M.S. degree based on course work and thesis.

Total credit hours for both the Group A and B is 30. Students of both groups must take 19 credit hours of theoretical courses of which 4 credit hours are compulsory and 15 credit hours are elective. For the elective part, students can choose five 3-credit hours courses from the list of optional courses. The choice of optional courses will depend on the availability of teaching faculties of the institute. In addition, there will be a two credit hours oral comprehensive course. The remaining credit hours are distributed as follows:

- Group **A**

  Students from Group A are required to take three statistical computing courses (AST 530, AST 531, and AST 532) and prepare either a project report or a report from internship (AST 550). The computing courses AST 530 and AST 531 are of 2 credit hours and the comprehensive computing course AST 532 is of 3 credit hours. The project report (AST 550) will carry 2 credit hours of which 40% weight will be allotted for presentation, 10% for supervisor and the remaining 50% will be allotted for report.

- Group **B**

  A selected number of students will be considered for Group B who are required to submit a thesis and defend it (AST 551). The course AST 551 will carry 6 credit hours of which 40% weight will be for thesis presentation and 60% weight for thesis. Students of Group B must take the comprehensive statistical computing course (AST 532), which will carry 3 credit hours. It is expected that all thesis students actively participate in seminars organized by the institute during the academic year.

Each M.S. student (Group A and Group B) will be required to give at least one seminar during the academic year. It is a non-credit course but compulsory. The grade to be assigned will be "Satisfactory" or "Not-Satisfactory". The internal members of the examination committee will evaluate the performance in the seminars.

The marks allocation for theoretical and computing courses will be as follows:

Theoretical			Computing		
Attendance	:	05	Attendance/assignment	:	10
In-course exam	:	25	In-course exam	:	30
Final exam	:	70	Final exam	:	60

There will be two in-course examinations for each of the theoretical and computing courses.

Courses for Group A

Courses	Credit Hour
Compulsory Credits	
Theoretical Courses	4
Statistical Computing Courses	7
MS Project or Internship	2
Oral	2
Seminar	Non-credit
Elective Credits	
Theoretical Courses	15
Total	30

Compulsory Credits for Group A

Course ID	Course Title	Credit Hour
AST 501	Applied Bayesian Statistics	4
AST 530	Statistical Computing I	2
AST 531	Statistical Computing II	2
AST 532	Comprehensive Statistical Computing	3
AST 540	Oral	2
AST 545	Seminar	Non-credit
AST 550	MS Project/Internship	2
Total		15

Courses for Group B

Courses	Credit Hour
Compulsory Credits for the Group B	
Theoretical Courses	4
Statistical Computing Courses	3
MS Thesis	6
Oral	2
Seminar	Non-credit
Elective Credits	
Theoretical Courses	15
Total	30

Compulsory Credits for Group B

Course ID	Course Title	Credit Hour
AST 501	Applied Bayesian Statistics	4
AST 532	Comprehensive Statistical Computing	3
AST 540	Oral	2
AST 545	Seminar	Non-credit
AST 551	MS Thesis	6
Total		15

Elective Credits for Groups A and B

Course ID	Course Title	Credit Hour
AST 510	Advanced Survival Analysis	3
AST 511	Environmental and Spatial Statistics	3
AST 512	Advanced Time Series Analysis	3
AST 513	Actuarial Techniques	3
AST 514	Advanced Operations Research	3
AST 515	Advanced Econometric Methods	3
AST 516	Advanced Population Studies	3
AST 517	Queueing Theory and Stochastic Processes	3
AST 518	Applied Multivariate Techniques	3
AST 519	Analysis of Longitudinal Data	3
AST 520	Adaptive Sampling	3
AST 521	Optimum Experimental Designs	3
AST 522	Statistical Signal Processing	3
AST 523	Meta Analysis	3
AST 524	Clinical Trials	3

Detailed Syllabus

AST 501: Applied Bayesian Statistics | **Credit 4**

Bayesian thinking: background, benefits and implementations; Bayes theorem, components of Bayes theorem - likelihood, prior and posterior; informative and non-informative priors; proper and improper priors; discrete priors; conjugate priors; semi-conjugate priors; exponential families and conjugate priors; credible interval; Bayesian hypothesis testing; building a predictive model.

Bayesian inference and prediction: single parameter models - binomial model, Poisson model, normal with known variance, normal with known mean; multi-parameter models - concepts of nuisance parameters, normal model with a non-informative, conjugate, and semi-conjugate priors, multinomial model with Dirichlet prior, multivariate normal model; posterior inference for arbitrary functions; methods of prior specification; method of evaluating Bayes estimator.

Summarizing posterior distributions: introduction; approximate methods: numerical integration method, Bayesian central limit theorem; simulation method: direct sampling and rejection sampling, importance sampling; Markov Chain Monte Carlo (MCMC) methods - Gibbs sampler, general properties of the Gibbs sampler, Metropolis algorithm, Metropolis-Hastings (MH) sampling, relationship between Gibbs and MH sampling, MCMC diagnostics - assessing convergence, acceptance rates of the MH algorithm, autocorrelation; evaluating fitted model - sampling from predictive distributions, posterior predictive model checking.

Linear model: introduction, classical and Bayesian inference and prediction in the linear models, hierarchical linear models - Bayesian inference and prediction, empirical Bayes estimation; generalized linear model - Bayesian inference and prediction (logit model, probit model, count data model); model selection - Bayesian model comparison.

Nonparametric and Semiparametric Bayesian models.

Text Books

1. Hoff PD (2009). A First Course in Bayesian Statistical Methods. Springer.
2. Gelman A, Carlin JB and Stern HS, Dunson DB, Vehtari A, and Rubin DB (2013). Bayesian Data Analysis, third edition. Chapman and Hall.

AST 510: Advanced Survival Analysis

Credit 3

Estimating the Survival and Hazard Functions: Introduction and notation, the Nelson-Aalen and Kaplan-Meier estimators, counting process and martingals, properties of Nelson-Aalen estimator.

Semiparametric Multiplicative Hazards Regression Model: Introduction, estimation of parameters, inclusion of strata, handling ties, sample size determinations, counting process form of a Cox model, time-dependent covariates, different types of residuals for Cox models, checking proportionality assumption.

Multiple Modes of Failure: Basic characteristics of model specification, likelihood function formulation, nonparametric methods, parametric methods, semiparametric methods for multiplicative hazards model.

Analysis of Correlated Lifetime Data: Introduction, regression models for correlated lifetime data, representation and estimation of bivariate survivor function.

Text Books

1. Therneau TM and Grambsch PM (2000). Modeling survival data: extending the Cox model, Springer.
2. Kalbfleisch JD and Prentice RL (2002). The statistical analysis of failure time data, 2^{nd} *edition*. Wiley.
3. Hougaard P (2000). Analysis of multivariate survival data. Springer.

AST 511: Environmental and Spatial Statistics — Credit 3

Review of non-spatial statistics and stochastic process, overview of different types of spatial data; random field and spatial process - geostatistical/point reference process, areal/lattice process and point process; spatial data concern.

Geostatistical data: real data examples, measure of spatial dependence- variogram and covariance, stationarity and isotropic, variograms and covariance functions, fitting the variograms functions; Kriging, linear geostatistical model - formulation, simulation, estimation and prediction, generalized linear geostatistical model - formulation, simulations, estimation and prediction. Areal data: neighborhoods, testing for spatial association, autoregressive models (CAR, SAR), estimation/inference; grids and image analysis, disease mapping. Point pattern data: locations of events versus counts of events, types of spatial patterns, CSR and tests - quadrat and nearest neighbor methods, K-functions and L-functions, point process models- estimation and inference, health event clustering.

Special topics in spatial modeling: Hierarchical models, Bayesian methods for spatial statistics, Bayesian disease mapping, Spatio-temporal modeling, more on stationarity. Use of R and GIS software for with emphasis on analysis of real data from the environmental, geological and agricultural sciences.

Text Books

1. Cressie N (1993). Statistics for Spatial Data, *Revised edition.* Wiley.
2. Banerjee S, Carlin BP, and Gelfand AE (2014). Hierarchical modelling and analysis for spatial data.*second edition* Chapman.
3. Cressie N and Wikle CK (2011). Statistics for Spatio-Temporal Data. Wiley.
4. Illian J, Penttine A, Stoyan H and Stoyan D (2008). Statistical analysis and modelling of spatial point patterns. Wiley.

AST 512: Advanced Time Series Analysis

Credit 3

Introduction: Forecasting Time Series, Estimation of Transfer Functions, Stochastic and Deterministic Dynamic Mathematical Models, Stationary and Nonstationary Stochastic Models for Forecasting and Control, Basic Ideas in Model Building. Time Series and Stochastic Processes, Stationary Stochastic Processes.

Seasonal Models: Parsimonious Models for Seasonal Time Series, Fitting versus Forecasting, Seasonal Models Involving Adaptive Sines and Cosines, General Multiplicative Seasonal Model, Some Aspects of More General Seasonal ARIMA Models, Structural Component Models and Deterministic Seasonal Components.

Nonlinear and Long Memory Models: Autoregressive Conditional Heteroscedastic (ARCH) Models, Generalized ARCH (GARCH) Models, Model Building and Parameter Estimation, Nonlinear Time Series Models, Long Memory Time Series Processes.

Multivariate Time Series Analysis: Stationary Multivariate Time Series, Vector Autoregressive-Moving Average (ARMA) Models and Representations, Relation of Vector ARMA to Transfer Function and ARMAX Model Forms, Forecasting for Vector Autoregressive-Moving Average Processes.

Text Books

1. Box GEP, Jenkins GM and Reinsel GC (2008). Time Series Analysis: Forecasting and Control, 4^{th} *edition*. Wiley.
2. Brockwell PJ and Davis RA (2013). Introduction to Time Series and Forecasting, 2^{nd} *edition*. Springer.

AST 513: Actuarial Techniques | **Credit 3**

Theory of interest in continuous time. Forces of interest and discount (constant and varying). Present and accumulated value calculations using non-level interest rates. Continuous annuities; valuation of continuous streams of payment, including the case in which interest conversion period differs from the payment period; continuous varying annuities. Bonds and related securities.

Definition and application of standard mortality probability symbols and force of mortality; relationship between survival distribution and life table functions; Continuous life annuities. Multiple decrement models. Net premiums; fully continuous premiums. Net premium reserves. Valuation theory for pension plans. The expanse factor and dividends. Introduction to risk theory: Purpose of the theory of risk; main problems in risk theory; individual risk models for a short term; applications of risk theory.

Principles of actuarial modeling. Familiarity with actuarial models: survival models, credibility models, risk theory models, ruin theory models, etc and their applications.

Text Books

1. Kellison SG (1991). Theory of Interest. Irwin.

AST 514: Advanced Operations Research

Credit 3

Special Types of Liner Programming Problems: Transportation problem, Transshipment problem, Assignment problem, Multidimensional problems.

Network Analysis: Terminology of networks, Shortest path problem, Minimum spanning tree problem, Maximum flow problem, Minimum cost flow pattern, Network simplex method, Project Planning and control with PERT-CPM.

Dynamic Programming: Characteristics of dynamic programming problems, Deterministic dynamic programming, Probabilistic dynamic programming.

Non-linear Programming: Sample application, Graphical illustration of non-linear programming problems, Types of non-liners programming problems, One-variable unconstrained optimization, Multivariate unconstrained optimization, Karush-Kuhn Tucker (KKT) conditions for constrained optimization, Quadratic programming, Separable Programming, Convex programming, Non-convex programming.

Inventory Models: The ABC inventory system, A generalized inventory model, Deterministic models, Probabilistic models, Just-in-time manufacturing system;

Text Books

1. Hillier FS, Lieberman GJ, Nag B and Basu P (2001). Introduction to operations research, 9^{th} *edition.* McGraw-Hill.

AST 515: Advanced Econometric Methods | **Credit 3**

Three-Stage Least Squares Estimation: The Three-Stage Least Squares Estimator (3SLS), Comparison between GMM 3SLS and Traditional 3SLS.

Linear Unobserved Effects Panel Data Models: Strict Exogeneity Assumptions on the Explanatory Variables, Some Examples of Unobserved Effects Panel Data Models, Estimating Unobserved Effects Models by Pooled OLS, Random Effects (RE) Methods, Estimation and Inference under the Basic Random Effects, A General FGLS Analysis, Fixed Effects (FE) Methods, Consistency of the Fixed Effects Estimator, Asymptotic Inference with Fixed Effects. The Hausman Test Comparing the RE and FE Estimators.

Nonlinear Models: Discrete Response Models, The Linear Probability Model for Binary Response, Probit and Logit, Maximum Likelihood Estimation of Binary Response Models, Specification Issues in Binary Response Models, Neglected Heterogeneity, Continuous Endogenous Explanatory Variables, A Binary Endogenous Explanatory Variable, Heteroskedasticity and Nonnormality in the Latent Variable Model, Estimation under Weaker Assumptions, Binary Response Models for Panel Data, Pooled Probit and Logit, Multinomial Response Models: Multinomial Logit, Probabilistic Choice Models. Ordered Response Models: Ordered Logit and Ordered Probit, Applying Ordered Probit to Interval-Coded Data, Corner Solution Outcomes and Censored Regression Models: Derivations of Expected Values, Inconsistency of OLS, Estimation and Inference with Censored Tobit, Pooled Tobit, Applying Censored Regression to Panel Data.

Text Books

1. Wooldridge JM (2010). Introductory Econometrics: A Modern Approach, 5^{th} *edition.* Cengage Learning.
2. Greene WH (2011). Econometric Analysis, 7^{th} *edition.* Prentice Hall.

AST 516: Advanced Population Studies

Credit 3

Fertility Determinants and models. Davis-Blake intermediate variables. Proximate determinants. Bongaarts model. Birth interval dynamics. Fecundity. Application of these models in the Bangladesh setting.

Estimation of population parameters from incomplete data. Estimation of mortality from census. Survivorship ratio. Estimate of infant and child mortality by indirect techniques such as Brass, Sullivan, Trussell and Feeney. Estimation of adult mortality from information on widowhood and orphanhood. Estimation of fertility by indirect techniques such as Brass, Hill, Coale-Trussell, relational Gompertz and reduced Gompertz model.

Population and Development: Inter-relation between population and development as envisaged value. Various population theories such as demographic transition theory. Emerging theories of population. Micro-economic theory of population. Recent contribution of Eastisliu, Becker, Caldwell etc.

Morbidity: Morbidity differentials and trends in Bangladesh. Health expectancy and burden of disease.

Manpower planning: Manpower in Bangladesh. Factors effecting manpower. Working life tables. Statistical analysis of manpower planning. Labor migration and its impact on the economy.

Population program of Bangladesh: Population policy. Population control and family planning. Evaluation of family planning programs. Use effectiveness and cost effectiveness. Multiple decrement life tables for measuring use-effectiveness. FP target setting models and impact assessment models.

Text Books

1. Chiang CL (1984). The life table and its applications. Krueger.
2. Bongaarts J and Potter RG (1983). Fertility, biology and behavior: an analysis of the proximate determinants of fertility. Academic Press.

AST 517: Queueing Theory and Stochastic Processes

Credit 3

Queueing theory: Classical M/M/1 queue, global and local balance, performance measures, Poisson arrivals see time averages (PASTA) property, M/M/1/S queueing systems, blocking probability, performance measures, multi-server systems M/M/m, performance measures, waiting time distribution of M/M/m, performance measures of M/M/m/m with finite customer population, Erlang loss systems, a more general queueing models: M/G/1, M/G/m, G/M/1 queueing systems and analysis.

Queueing networks: open queueing networks, analysis of tandem queues, applications of tandem queues in data networks, Jackson queueing networks, performance measures for open networks, closed queueing networks: Jackson closed queueing networks, steady-state probability distribution, application of closed queueing networks.

Reliability theory: structure functions, minimal path and minimal cut sets, reliability of systems of independent components, bounds on the reliability function, system life as a function of component lives, expected system lifetime, systems with repair.

Brownian motion and stationary processes: Brownian motion, hitting times, maximum variable, variations on Brownian motion, Brownian motion with drift, geometric Brownian motion, pricing stock options, white noise, Gaussian processes, stationary and weakly stationary processes, harmonic analysis of weakly stationary processes.

Text Books

1. Chee-Hock N and Boon-Hee S (2008). Queueing modelling fundamentals with applications in communication networks. John Wiley & Sons, Chichester.
2. Ross SM (2010). Introduction to probability models, 10^{th} *edition*. Academic press, New York.

AST 518: Advanced Multivariate Techniques — Credit 3

Principal Components: population principal components, summarizing sample variations by principal components, graphing the principal components, large sample inference.

Factor Analysis: the orthogonal factor models, methods of estimation (maximum likelihood estimates and principal factor analysis), selection of loadings and factor (factor rotation, varimax rotation, quartimax rotation, oblimin rotations), factor scores, structural equations models.

Canonical Correlation Analysis: canonical variates and canonical correlations, sample canonical variates and sample canonical correlations, large sample inference.

Discrimination and Classification: separation and classification two populations, classification of two multivariate normal populations, evaluating classification functions, Fisher's discriminant function, classification with several populations, Fisher's method for discriminating several populations.

Clustering: similarity measures, hierarchical clustering methods, nonhierarchical clustering methods, Multidimensional scaling.

Text Books

1. Johnson RA, Wichern W (2002). Applied Multivariate Statistical Analysis. Pearson.
2. Srivastava KS (2002). Methods of Multivariate Statistics. Wiley.

AST 519: Analysis of Longitudinal Data

Credit 3

Longitudinal data: concepts, examples, objectives of analysis, problems related to one sample and multiple samples, sources of correlation in longitudinal data, exploring longitudinal data.

Linear model for longitudinal data: introduction, notation and distributional assumptions, simple descriptive methods of analysis, modelling the mean, modelling the covariance, estimation and statistical inference.

ANOVA for longitudinal data: fundamental model, one sample model, sphericity condition; multiple samples models.

Linear mixed effects models: introduction, random effects covariance structure, prediction of random effects, residual analysis and diagnostics.

Extension of GLM for longitudinal data: review of univariate generalized linear models, quasi-likelihood, marginal models, random effects models, transition models, comparison between these approaches; the GEE methods: methodology, hypothesis tests using wald statistics, assessing model adequacy; GEE1 and GEE2. Generalized Linear Mixed Models (GLMM): introduction, estimation procedures: Laplace transformation; Penalized Quazi-Likelihood (PQL); Marginal Quazi Likelihood (MQL); Numerical integration: Gaussian quadrature, Adaptive Gaussian quadrature, Monte Carlo Integration; Markov Chain Monte Carlo sampling; comparison between these methods

Statistical analysis with missing data: missing data, missing data pattern, missing data mechanism, imputation procedures, mean imputation, hot deck imputation. estimation of sampling variance in the presence of non-response, likelihood based estimation and tests for both complete and incomplete cases, regression models with missing covariate values, applications for longitudinal data.

Text Books

1. Verbeke G and Molenberghs G (2000). Linear Mixed Model for Longitudinal Data. Springer.
2. Molenberghs G and Verbeke G (2005). Models for Discrete Longitudinal Data. New York: Springer-Verlag.
3. Diggle PJ, Heagerty P, Liang K-Y, and Zeger SL (2002). Analysis of longitudinal data, 2^{nd} *edition*. Oxford.

AST 520: Adaptive Sampling

Credit 3

Design and Model unbiased estimators; Fixed and Stochastic population sampling theory.

Adaptive sampling deigns; Detectability in adaptive sampling; constant and unequal detectabilities for adaptive design.

Adaptive cluster sampling; Initial random sample with and without replacement; Initial unequal probability sampling; Expected sample size and cost; Comparative efficiencies of adaptive and conventional sampling.

Systematic and strip adaptive cluster sampling; Stratified adaptive cluster sampling; Adaptive allocation in stratified sampling; Sample sizes based on observations in each strata and from previous strata; Comparison of systematic and stratified adaptive sampling with conventional sampling procedures; Adaptive cluster sampling based on order statistics.

Multivariate aspects of adaptive sampling; Multivariate conditions for adding neighbourhoods; Design-unbiased estimation for multivariate approach;

Text Books

1. Thompson SK and Seber GAF (1996). Adaptive Sampling. Wiley.
2. Thompson SK (1992). Sampling. Wiley.

AST 521: Optimum Experimental Designs

Credit 3

Optimum design theory : continuous and exact designs, the general equivalence theorem, algorithms for continuous designs and general equivalence theorem, function optimization and continuous design

Criteria of optimality : A-, D-, and E-optimality; D_A-optimality, D_S-optimality, c-optimality, linear optimality; compund design criteria.

D-optimum designs: properties of D-optimum designs, sequential construction of optimum designs, polynomial regression in variable, second-order model with several variables.

Algorithms for constructing of exact D-optimum designs: the exact design problem, basic formulae for exchange algorithm, sequential algorithms, non-sequential algorithms, the KL and BLKL exchange algorithms.

Experiments with both qualitative and quantitative factors, blocking response surface designs, mixture experiments, non-linear models, Bayesian optimum designs, model checking and designs for discriminating between models, compund design criteria, generalized linear models.

Text Books

1. Atkinson AC, Donev AN, and Tobias RD (2008). Optimum experimental designs with SAS. Oxford.

AST 522: Statistical Signal Processing | **Credit 3**

Introduction to signals: Signals and their classification; real world analog signals: audio, video, biomedical (EEG, ECG, MRI, PET, CT, US), SAR, microarray, etc; digital representation of analog signals; role of transformation in signal processing. Orthogonal representation of signals. Review of exponential Fourier Series and its properties.

Signal estimation theory: Estimation of signal parameters using ML, EM algorithm, minimum variance unbiased estimators (Rao-Blackwell theorem, CRLB, BLUE), Bayesian estimators (MAP, MMSE, MAE), linear Bayesian estimators.

Signal detection theory: Detection of DC signals in Gaussian noise: detection criteria (Bayes risk, Probability of error, Neyman-Pearson), LRT; detection of known signals in Gaussian noise: matched filter and its performance, minimum distance receiver; detection of random signals in Gaussian noise: the estimator correlator.

Applications: Scalar quantization, image compression, pattern recognition, histogram equalization, segmentation, application of signal estimation and detection theory to signal communication, signal recovery from various types of linear and nonlinear degradations, copyright protection, enhancement, etc.

Text Books

1. Soliman SS and Mandyam DS (1998). Continuous and discrete signals and systems, 2^{nd} *edition.* Prentice-Hall.
2. Kay SM (1993). Fundamentals of statistical signal processing: estimation theory. Prentice-Hall.
3. Kay SM (1998). Fundamentals of statistical signal processing: detection theory. Prentice Hall.
4. Gonzalez RC and Woods RE (2008). Digital Image Processing, 3^{rd} *edition.* Pearson Education, Inc.

AST 523: Meta analysis | **Credit 3**

Introduction to systematic review and meta analysis: motivation, strengths and weakness of meta-analysis, problem formulation (why study meta analysis), systematic review process;

Types of results to summarize; overview of effect size; effect size calculation for both continuous and discrete data;

Combining effect size from multiple studies; fixed effect and random effects models and their estimation; heterogeneity between studies and its estimation techniques; test of homogeneity in meta analysis; prediction intervals; subgroup analysis, Meta regression: random effect meta regression, baseline risk regression;

Publication bias in meta analysis; Power analysis for meta analysis; Effect size rather than P-values; Meta analysis based on direction and P-values, Reporting the results of meta analysis;

Introduction to Bayesian approach to meta analysis; Meta analysis for multivariate/longitudinal data; Network meta analysis;

Text Books

1. Borenstein M, Hedges LV, Higgins JPT and Rothstein HR (2009). Introduction to Meta-Analysis, John Wiley & Sons, UK.
2. Hartung J and Knapp G and Sinha BK (2011). Statistical Meta-Analysis with Applications. John Wiley & Sons, UK

AST 524: Clinical Trials | **Credit 3**

Statistical approaches for clinical trials: introduction, comparison between Bayesian and frequentist approaches and adaptivity in clinical trials. Phases of clinical trials, pharmacokinetics (PK) and pharmacodynamics (PD) of a drug, dose-concentration-effect relationship and compartmental models in pharmacokinetic studies.

Phase I studies: Determining the starting dose from preclinical studies. Rule-based designs: 3+3 design, Storer's up-and-down designs, pharmacologically-guided dose escalation and design using isotonic regression. Model-based designs: continual reassessment method and its variations, escalation with overdose control and PK guided designs.

Phase II studies: Gehan and Simon's two-stage designs. Seamless phase I/II clinical trials: TriCRM, EffTox and penalised D-optimum designs for optimum dose selection.

Phase III studies: Randomised controlled clinical trial, group sequential design and multi-arm multi-stage trials in connection with confirmatory studies.

Text Books

1. Berry SM, Carlin BP, Lee JJ, and Muller P (2010). Bayesian adaptive methods for clinical trials. CRC press

2. Rosenbaum SE (2012). Basic pharmacokinetics and pharmacodynamics: An integrated textbook and computer simulations. John Wiley & Sons.

AST 530: Statistical Computing I

Credit 2

Computing problems related to AST 501: Applied Bayesian Statistics, and AST 523: Meta Analysis

AST 531: Statistical Computing II

Credit 2

Computing problems related to AST 518: Applied Multivariate Techniques, and AST 519: Analysis of Longitudinal Data

AST 532: Comprehensive Statistical Computing

Credit 3

This is a comprehensive statistical computing course, which is compulsory for all the M.S. students. It will cover computing problems related to all the courses studied in the academic year. For this course, 30% weight will be alloted to the in-course examinations, 10% weight will be allotted to the lab-based assignments, and remaining 60% weights for the final examination. Part of the examinations will be held in computer lab.

AST 540: Oral

Credit 2

Each student (Group A and Group B) should be examined orally by a committee of selected members at the end of the academic year.

AST 545: Seminar | **Non-Credit**

The internal members of the examination committee will evaluate the performance in the seminars.

AST 550: M.S. Project/Internship | **Credit** 2

Each student should be either in the project report group or in the internship group that the student will decide after discussing with the respective assigned supervisor. Students must submit their project report or internship report within 2 months of completing the final examination. The internal members of the examination committee will evaluate the performance of the students in the seminars and the project report or internship report will be evaluated by two examiners nominated by the examination committee. A supervisor cannot evaluate the project or internship report that s/he has supervised. This course will carry 2 credit hours. For this course, 50% weight of the course will be allotted to report, 10% for supervisor and the remaining 40% will be for seminar presentation.

AST 551: M.S. Thesis | **Credit** 6

After three months of the start, each Group B student will submit a three to five page thesis proposal and present his/her proposal, which will be evaluated by the internal members of the examination committee. Written evaluation on the proposal will be provided to the students explaining the possible improvement and in case of "Not satisfactory" proposals, the reasons for "Not satisfactory" performance will be stated in the written evaluation. In case of "Not satisfactory" performance the examination committee may give the student a second opportunity for proposal presentation. Students with "Not-Satisfactory" performance at the end will be transferred to the Group A. The final submission of the thesis will be required within 4 months of the completion of final exam. Thesis will be examined by two external (outside the institute) examiners. Should it be required, the examination committee may consider one internal and one external examiner. Submitted thesis has to be defended at a presentation evaluated by the members of the examination committee. 40% weight will be allotted for thesis defense and remaining 60% for thesis itself.
