Institute of Statistical Research and Training
University of Dhaka

Syllabus

B.S. Honors Program in Applied Statistics
Session : 2013-2014

www.isrt.ac.bd/syllabus

B.S. Honors Program in Applied Statistics

The B.S. honors course in Applied Statistics is an integrated four-year program. The program includes courses of both theoretical and applied nature, but more emphasis is given on the applications of the statistical techniques to real life situations. The course is so designed that after successful completion, the graduates are equipped to work efficiently and completely in government and non-government organizations, research organizations, service departments and other related fields.

The examination consists of four parts, one at the end of each academic year. Each student has to take a total of 140 credits over four academic years. These include 107 credits of theoretical courses, 22 credits of computing courses and 8 credits of oral. For theoretical courses, 25 credits will be from courses of Mathematics, Economics and Computer Science. Thirty percent marks of the theoretical courses and forty percent marks of the computing courses will be allotted for in-course examination.

The marks allocation for theoretical courses will be as follows:

Attendance	:	05
In-course exam	:	25
Final exam	:	70

The marks allocation for computing courses will be as follows:

Attendance/assignment	:	10
In-course exam	:	30
Final exam	:	60

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

A student with high academic attainment in S.S.C and H.S.C. or equivalent levels with Mathematics as a subject of study is eligible for admission. The regulations for admission of the students and the examinations will be same as those of the B.S. honors courses in the Faculty of Science unless otherwise stated.

Distribution of courses, credits, marks and detailed syllabus are as follows:

Courses for the First Year

Course ID	Course Title	Credit
AST 101	Elements of Applied Statistics	4
AST 102	Elements of Probability	4
AST 103	Programming with Fortran and C	3
AST 104	Basic Algebra and Linear Algebra (Part A & B)	4
AST 105	Differential and Integral Calculus (Part A & B)	4
AST 106	Principles of Economics	4
AST 130	Statistical Computing I	2
AST 131	Statistical Computing II	2
AST 140	Oral I	2
Total		29

Courses for the Second Year

Course ID	Course Title	Credit
AST 201	Probability Distributions and Simulation	3
AST 202	Sampling Distributions and Order Statistics	3
AST 203	Statistical Inference I	4
AST 204	Design of Experiments	3
AST 205	Introduction to Demography	3
AST 206	Introductory Sampling Methods	3
AST 207	Data Analysis using S Language and MATLAB	3
AST 208	Mathematical Methods	3
AST 230	Statistical Computing III	2
AST 231	Statistical Computing IV	2
AST 232	Statistical Computing V	2
AST 240	Oral II	2
Total		33

Courses for the THIRD Year

Course ID	Course Title	Credit
AST 301	Design and Analysis of Factorial Experiments	4
AST 302	Advanced Sampling Techniques	3
AST 303	Applied Regression Analysis	4
AST 304	Epidemiology	3
AST 305	Population Studies	3
AST 306	Social Statistics and Social Development	3
AST 307	Research Planning, Monitoring and Evaluation	3
AST 308	Data Analysis using SPSS and SAS	3
AST 309	Mathematical Analysis	4
AST 330	Statistical Computing VI	2
AST 331	Statistical Computing VII	2
AST 332	Statistical Computing VIII	2
AST 340	Oral III	2
Total		38

Courses for the FOURTH Year

Course ID	Course Title	Credit
AST 401	Advanced Probability and Stochastic Processes	3
AST 402	Statistical Inference II	4
AST 403	Applied Multivariate Data Analysis	3
AST 404	Econometric Methods	3
AST 405	Lifetime Data Analysis	4
AST 406	Industrial Statistics and Operations Research	3
AST 407	Actuarial Statistics	3
AST 408	Modeling Time Series Data	3
AST 409	Generalized Linear Models	3
AST 430	Statistical Computing IX	2
AST 431	Statistical Computing X	2
AST 432	Statistical Computing XI	2
AST 440	Oral IV	2
AST 450	Project and Seminar	3
Total		40

Detailed Syllabus - First Year

AST 101: Elements of Applied Statistics | **Credit 4**

Introduction to statistics: meaning of statistics; scopes and limitations; concepts of descriptive and inferential statistics; basic concepts: data, sources of data - primary and secondary data; population, sample, parameter, statistic; variables and types of variable: qualitative and quantitative discrete, continuous; scales of measurements; classification of variable by scales of measurements.

Organization and presentation of data: graphical presentation for qualitative and quantitative data; use of excel software; sorting data, grouping qualitative and quantitative data: construction of frequency distribution and relative frequency distribution; graphical presentation of frequency distribution- histogram, frequency polygon, ogive.

Concept of distribution: location, scale (spread) and shape, illustration with stem and leaf diagram; use of excel software; descriptive measures of data; measures of location; measures of dispersion; moments and their interrelationship; measures of skewness and kurtosis; three and five number summary; box-plot and modified box-plot; use of excel software.

Description of bivariate data: bivariate frequency distribution; graphical presentation of bivariate data; contingency table; concept of association between two variables; percentage table and interpretation of cell frequencies; measures of association for nominal and ordinal variables; measures of association for interval or ratio variables; correlation; relationship between two variables: simple linear regression; use of excel software; basic issues in inferential statistics.

Text Books

1. Newbold, P (2004). Statistics for business and economics, 3^{rd} *edition.* Prentice-Hall.
2. Weiss, N (2007). Introduction to statistics, 7^{th} *edition.* Addison Wesley.

AST 102: Elements of Probability | **Credit 4**

Combinatorial analysis: basic principles of counting, permutations, combinations; axioms of probability: sample space and events, axioms of probability, sample spaces

having equally likely outcomes, probability as a measure of belief; conditional probability and independence: conditional probabilities, Bayes formula, independent events.

Random variables: introduction, discrete random variables, expectation, expectation of a function of a random variable, variance, Bernoulli and binomial random variables, Poisson random variable, other discrete random variables (geometric, negative binomial, hypergeometric); expected value of a sums of random variables; properties of cumulative distribution function; continuous random variables: expectation and variance of continuous random variable, normal random variable, normal approximation to binomial distribution, exponential random variables.

Jointly distributed random variables: joint distribution functions, independent random variables, sums of independent random variables, conditional distributions (discrete and continuous cases); properties of expectation: expectation of sums of random variables, covariance, variance of sums, correlations, conditional expectation, moment generating functions, probability generating function.

Text Books

1. Ross, SM (2009). A first course in probability, 8^{th} *edition.* Prentice-Hall.

AST 103: PROGRAMMING WITH **Fortran** AND **C** | **Credit 3**

Introduction to programming: algorithm, flowchart, code (program); levels of programming: machine level, assembly level and high level language; execution of code: translator, compiler, interpreter, assembler; steps of execution: compilation, link, run.

Fortran: early development; standardization; precautions, creating source code, compiling, linking ; basic Fortran concepts: statements, expression and assignments, integer and real data types, do loops, functions, arrays; program structure and layout: Fortran character set, statement and lines, statement types and order; constants, variables, and arrays; character handling logic: character facilities, substrings, expressions, assignment statements, relational and logical expressions; control statements: control structures, if-blocks, do-loops, logical if statements; intrinsic functions, statement functions, external procedures, arrays as arguments, subroutine, call, return, function statements; input/output facilities: files, i/o units, records, external files, internal files, format specifications, format data descriptors; data statements;

An overview of C: the origins of the C language, compilers versus interpreters; variables, constants, operators, and expressions: data types, declaration of variables,

assignment statements, constants, operators, expressions; program control statements: C statements, conditional statements, loop statements, labels; functions: the return statement, function arguments, arguments to main(), returning pointers, pointers to functions; arrays: single-dimension arrays, passing single dimension arrays to functions, two- and multi-dimensional arrays, arrays and pointers, allocated arrays, array initialization;

Applications of Fortran and C programming in data analysis: frequency distributions, data summary, e.g., mean, median, maximum, minimum, matrix operations, calculation of different rates, fitting simple linear regression, sorting a vector, optimizing non-linear functions using Newton-Raphson iterative procedure, numerical integration and differentiation.

Text Books

1. Dietel, PJ and Deitel, HM (2010). C how to program, 7^{th} *edition*. Pearson.
2. Page, CG (1999). Professional programmer's guide to Fortran77. University of Leicester.

AST 104: Basic Algebra and Linear Algebra | **Credit 4**

Part A: Basic Algebra

Theory of numbers: unique factorization theorem; congruencies; Euler's phi-function; inequalities: order properties of real numbers; Weierstrass', Chebysev's and Cauchy's inequalities; inequalities involving means; complex numbers: field properties; geometric representation of complex numbers; operations of complex numbers; summation of algebraic and trigonometric finite series; theory of equations: relations between roots and coefficients; symmetric functions of roots; Descartes rule of signs; rational roots; Newton's method.

Part B: Linear Algebra

Vectors: operations with vectors; scalar product; norm of a vector; vectors in n-space, Eucledian n-space; vector space and sub-space; linear combinations of vectors; spanning set; linear dependence and independence; basis and dimension; inner product spaces; orthogonal and orthonormal basis; Gram-Smidt orthogonalization process;

System of linear equation: homogeneous and non-homogeneous; introduction of matrix; solution using Gauss, Gauss-Jordan elementary operations; definition and operations using matrices; different types of matrices; transpose of a matrix; trace

of a matrix; determinant of a square matrix; adjoint of a square matrix; inverse of a matrix; properties of inverse; elementary matrix and method for finding inverse using elementary operations and by partitioning; solution of system of linear equations by matrix inverse and Cramer's rule; rank of matrices and related theory; linear transformation; eigenvalue and eigenvectors; diagonalization, orthogonal diagonalization; fundamentals of quadratic forms and it's application in statistics; differentiation of matrix; g-inverse.

Text Books

1. Anton, H and Rorres, C (2005). Elementary linear algebra, 4^{th} *edition.* Wiley.
2. Ayres, F (1995). Theory and problems of modern algebra. McGraw-Hill.

AST 105: Differential and Integral Calculus **Credit 4**

Part A: Differential Calculus

Real numbers and function; limit and continuity of functions of one variable; derivative of a function of one variable; geometric interpretation of the derivative; differentiation formulas; the chain rule; implicit differentiation; derivatives from parametric equations; higher order derivatives; Leibnitiz's theorem; increasing and decreasing functions; extrema of functions; concavity; Rolle's mean value theorems; applications of the theory of extrema, velocity and acceleration related rates; differentials.

Part B: Integral Calculus

The anti derivatives (indefinite integral); elementary integration formulas; integration by parts; integration by substitution; integration of rational functions; the definite integral; fundamental theorem of calculus; properties of definite integrals; evaluation of definite integrals; simple reduction formulas.

Indeterminate forms; infinite limits; tangent; normal; curvature; asymptote; curve tracing; areas; arc lengths; volumes and surfaces of solids of revolution; functions of several variables; limit and continuity; partial derivatives; chain rule; total differentials; Jacobian extrema; Lagrange multiplier; multiple integrals; evaluation of double and triple integrals by iteration; area, volume and mass by double and triple integration.

Formulation of simple applied problems in terms of differential equations; equations of the first order and their solutions; singular solutions; geometric applications; lin-

ear equations with constant coefficients; method of undermined coefficients; variation of parameters and inverse differential operators; simple cases of linear equations with variable coefficients.

Text Books

1. Anton, H (1995). Calculus with analytic geometry, 5^{th} *edition*. Wiley.
2. Stewart, J (2006). Calculus: early transcendentals (Stewart's calculus series).
3. Ross, SL (1980). Introduction to ordinary differential equations, 4^{th} *edition*. Wiley.

AST 106: Principles of Economics | **Credit 4**

Definition and scope of economics; theory of demand and supply; demand schedule; supply schedule; equilibrium of demand and supply; elasticity of demand and supply: measurement of elasticity; price elasticity of demand and supply.

Demand and consumer behavior; utility theory; equi-marginal principle; indifference curve analysis: consumers surplus; individual and market demand; derivation of demand curve; theory of production: production function; total, average and marginal product; law of diminishing returns; factors of production; pricing of factors of production; division of labor; localization of industries; returns to scale; law of variable proportion; isoquants; Cob-Douglas and CES production function; theory of cost; fixed and variable cost; total and marginal costs; least cost rule; opportunity cost.

Market structure: perfect and imperfect competition; pricing under monopoly, oligopoly and monopolistic competition; short-run and long-run equilibrium analysis; theory of income distribution; theories of wage, rent and interest; key concepts of macro economics: objectives and instrument of macro economics; measurement of economic activity; tools of macro economic policy; consumption and investment; theories of economic growth; stabilizing the economy and price stability.

Text Books

1. Samuelson, PA and Nordhaus, WD (2004). Economics, 16^{th} *edition*. McGraw Hill.
2. Koutsoyiannis, A (1975). Modern microeconomics, 2^{nd} *edition*. Macmillan.

AST 130: Statistical Computing I — **Credit 2**

Computing problems related to the courses AST 101 (Elements of Applied Statistics) and AST 102 (Elements of Probability).

AST 131: Statistical Computing II — **Credit 2**

Computing problems related to the courses AST 103 (Programming with Fortran and C), AST 104 (Basic and Linear Algebra), and AST 106 (Principles of Economics).

AST 140: Oral I — **Credit 2**

Detailed Syllabus - Second Year

AST 201: Probability Distributions and Simulation

Credit 3

Idea of probability distribution and uses in statistics; properties of probability distributions; conditional distribution and expectations; moments and cumulants; characteristic function; finding moments of probability distributions: uniform, exponential, gamma, beta, log-normal, Cauchy, Laplace (double) exponential, inverse Gaussian, Maxwell, Pareto, triangular, Rayleigh, Weibull, logistic, Gumbel; bivariate probability distributions and their moments: bivariate normal, bivariate binomial, bivariate Poisson; truncated distributions; compound and mixture distributions; family of distributions: exponential family, location-scale family, Pearsonian, and Tukey lambda.

Concepts of simulation and its uses in statistics; random number generations: congruential generators, seeding; random variate generations: inversion method (direct method), rejection method (indirect method); simulating discrete random variables: binomial and Poisson distributions; simulating normal random variables: rejection with exponential envelope, Box-Muller algorithm; simulating bivariate random variables; Monte-Carlo integration: hit-and-miss method, improved Monte-Carlo integration; variance reduction: antithetic sampling, importance sampling, control variates.

Text Books

1. Balakrishnan, N and Nevzorov, VB (2003). A primer on statistical distributions. Wiley.
2. Banks, J, Carson, J, Nelson, B and Nicole, D (2004). Discrete-events system simulation. Prentice-Hall.
3. Jones, O, Maillardet, R and Robinson, A (2009). Introduction to scientific programming and simulation using R. Chapman & Hall/CRC.

AST 202: Sampling Distributions and Order Statistics

Credit 3

Sampling and Sampling Distributions: Expectations of functions of random variables: expectation two ways, sums of random variables, product and quotient;

Cumulative distribution function technique: distribution of minimum and maximum, distribution of sum of difference of two random variables, distribution of product and quotient; Moment generating function technique: description of technique, distribution of sums of independent random variables; The transformation $Y = g(X)$: distribution of $Y = g(X)$, probability integral transformation; Transformations: discrete random variables, continuous random variables.

Sampling: basic concepts of random samples, inductive inference, populations and samples, distribution of samples, statistic and sample moments; Sample mean: mean and variance, law of large numbers, central limit theorem, Bernoulli and Poisson distribution, exponential distribution, uniform distribution, Cauchy distribution; sampling from the normal distributions: role of normal distribution in statistics, sample mean, chi-square distribution, the F-distribution, Student's t-distribution; non-central distributions: non-central chi-squared, t, and F distributions; definitions, derivations, properties.

Order Statistics: Concepts of order statistics and their applications; distributions of different single order statistics; joint distribution of two or more order statistics; distributions of maximum, minimum, range, median, and other quantiles. moments of order statistics; estimation based on order statistics; maximum likelihood estimation; approximate maximum likelihood estimation.

Text Books

1. Hogg, RV and Craig, AT (2005). Introduction to mathematical statistics, 6^{th} *edition*. Pearson.
2. Arnold, BC, Balakrishnan, N and Nagaraja, HNA (1992). First course in order statistics. Wiley.

AST 203: Statistical Inference I | **Credit 4**

Basic Concepts: Fundamental ideas of statistical inference; parametric and non-parametric inference; estimators, statistics, parameters, theory and reality; sampling distributions and uses in inference.

Estimation: Estimation of parameters and fitting of probability distributions; parameter estimation: method of moments, method of least squares, method of maximum likelihood - properties of maximum likelihood estimators, Bayes estimator; properties of a good point estimator; method of evaluating estimators: mean squared error; best unbiased estimator - efficiency and the Cramer-Rao lower bound; sufficiency - sufficient statistics, properties of a sufficient statistics, exponential family

and factorization theorem, the Rao-Blackwell theorem, minimal sufficient statistics, complete statistics.

Interval estimation: introduction; method of constructing confidence interval - pivotal quantity, exact and approximate confidence interval; large- and small-sample confidence intervals; selecting the sample size; simultaneous confidence region; Bayesian interval estimation; methods of evaluating interval estimators: size and coverage probability.

Test of Hypothesis: Elements of statistical hypothesis test; approaches to hypothesis testing: Neyman-Pearson approach, Fisher approach and Jeffreys' approach; common tests based on normal distribution: one sample settings, two sample (independent and paired) settings, more than two sample settings; the duality of confidence intervals and hypothesis tests; exact and large sample test; evaluating statistical test procedure - power of tests, optimal test - Neyman-Pearson lemma; most powerful tests; composite hypotheses; generalized likelihood ratio test; uniformly most powerful tests; unbiased tests; goodness-of-fit test - probability plots, test for normality, chi-square goodness of fit test, Kolmogorov-Smirnov test; statistical test applied to categorical data problem: introduction, Fisher's exact test, the chi-square test of homogeneity, chi-square test of independence.

Text Books

1. Casella, G and Berger, RL (2002). Statistical inference, 2^{nd} *edition.* Duxbury.
2. Hogg, RV and Craig, AT (2004). Introduction to mathematical statistics, 6^{th} *edition.* Macmillan.
3. Rice, JA (2007). Mathematical statistics and data analysis, 3^{rd} *edition.* Duxbury Press.

AST 204: Design of Experiments | **Credit 3**

Introduction to design of experiments: strategy of experimentation; some typical examples of experimental design; basic principles; guidelines for designing experiments.

Experiments with a single factor: the analysis of variance; analysis of fixed effects model; estimation of model parameters; unbalanced data; model adequacy checking; regression model, comparisons among treatment means, graphical comparisons of means, contrasts, orthogonal contrasts, multiple testing, Scheffe's method, comparing pairs of treatment means, comparing treatment means with a control; Determining sample size; operating characteristic curve, specifying standard deviation

increase, confidence interval estimation method; discovering dispersion effects; regression approach to analysis of variance; least squares estimation of the model parameters, general regression significance test; nonparametric methods in analysis of variance; the Kruskal-Wallis test.

Randomized blocks, Latin squares, and related designs: the randomized complete block designs (RCBD); statistical analysis of RCBD, model adequacy checking; estimating model parameters; Latin square design; Graeco-Latin square design; balanced incomplete block design (BIBD); statistical analysis of BIBD; least squares estimation of BIBD; recovery of intra-block information in the BIBD.

Text Books

1. Montgomery, DC (2001). Design and analysis of experiments, 5^{th} *edition.* Wiley.

AST 205: Introduction to Demography | **Credit 3**

Basic concept of demography; role and importance of demographic/population studies; sources of demographic data: census, vital registration system, sample surveys, population registers and other sources especially in Bangladesh.

Errors in demographic data: types of errors and methods of testing the accuracy of demographic data; quality checking and adjustment of population data; post enumeration check (PEC) and detection of errors and deficiencies in data and the needed adjustments and corrections.

Fertility: basic measures of fertility; crude birth rate, age specific fertility rates (ASFR), general fertility rate (GFR), total fertility rate (TFR), gross reproduction rate (GRR) and net reproduction rate (NRR), child-woman ratio; concept of fecundity and its relationship with fertility.

Demographic theory: transition theory and the present situation in Bangladesh; Malthus' theory and its criticism. mortality: basic measures of mortality: crude death rate (CDR), age specific death rates (ASDR), infant mortality rate, child mortality rate, neo-natal mortality rate; standardized death rate its need and use; direct and indirect standardization of rates; commonly used ratios: sex ratio, child-woman ratio, dependency ratio, density of population.

Fertility and mortality in Bangladesh since 1951: reduction in fertility and mortality in Bangladesh in recent years; role of socio-economic development on fertility and mortality.

Nuptiality: marriage, types of marriage, age of marriage, age at marriage and its effect on fertility, celibacy, widowhood, divorce and separation, their effect on fertility and population growth.

Migration: definition, internal and international migration; sources of migration data; factors affecting both internal and international migration, laws of migration; impact of migration on origin and destination, its effect on population growth, age and sex structure, labor supply, employment and unemployment, wage levels, and other socio-economic effects; migration of Bangladeshis abroad and its impact on overall economic development of the country.

Text Books

1. Siegel, SJ and Swanson, DA (2004). The methods and materials of demograph, 2^{nd} *edition*.

AST 206: Introductory Sampling Methods | **Credit 3**

Role of sampling theory; requirements of a good sample design; units; population; sampling units; sampling frame and related problems; uses of sample survey; random or probability sampling and non-random or purposive sampling; bias; precision and accuracy of estimates; different types of errors associated with sampling and complete enumeration.

Simple random sampling: advantages and disadvantages; drawing of samples; with and without replacement sampling- estimates, standard errors and confidence intervals; simple random sampling for proportion and ratio estimate, standard error and confidence interval; determination of sample size for specified precision.

Systematic sampling: use, limitation, estimates, bias, standard error and efficiency; comparison with simple random sampling; systematic sampling for populations with linear trend; methods for dealing with population with linear trend or periodic variation.

Stratification: reasons for stratification; formulation and number of strata; stratified random sampling estimates, standard error and confidence interval; allocation of samples to strata equal allocation, proportional allocation, Neyman allocation and optimum allocation; stratified sampling for proportions; post stratification and quota sampling.

Use of supplementary information: ratio estimation examples, estimate bias, mean squared error, approximate variance; conditions for unbiased ratio estimation; unbiased ratio-type estimates; necessity and limitation of ratio estimates; ratio estimates

in stratified random sampling; comparison of the combined and separate estimates; product and difference estimation.

Regression estimation: examples, assumptions, properties and limitations; bias and approximate variance; estimate of the variance; regression estimates in stratified sampling combined and separate estimates; comparative merits and demerits of ratio and regression estimates.

Cluster sampling: reasons, formation of clusters, size of clusters; simple cluster sampling with equal and unequal sized clusters estimates, bias, standard error and efficiency; comparison with simple random sampling and systematic sampling; determination of optimum cluster size.

Stratified cluster sampling: advantages, estimates, bias, standard error and efficiency; comparison with simple random sampling, systematic sampling and usual stratified random sampling.

Text Books

1. Cochran, WG (1977). Sampling techniques, 3^{rd} *edition.* Wiley.
2. Lohr, SL (1998). Sampling: design and analysis. Duxbury.

AST 207: Data Analysis using S Language and MATLAB

Credit 3

Introduction to R: Introduction, arithmetic, variables, functions, vectors, matrices, missing data, expressions and assignments; data structures: factors, dataframes, lists; input and output: input from different types of files, output to a file; functions; apply family; graphics: graphical parameters, graphical augmentation, mathematical typesetting, grouped graphs, 3d-plots.

Programming: Basic programming: logical vectors and relational operators; branching with `if`, looping with `for`, `while`; basic debugging; writing your own functions; root-finding: fixed-point iteration, the Newton-Raphson method; numerical differentiation and integration: trapezoidal rule, Simpson's rule, adaptive quadrature, built-in functions; optimisation: the golden section search method, Newtons method for optimisation, Newtons method in higher dimensions, bulid-in functions.

Data analysis: Descriptive statistics and graphics: q-q plots, boxplots, summary statistics, frequency tables; simulation: simulating random number and random variate, rejection sampling and importance sampling, simulating probability and sampling distributions; numerical approximation: Monte Carlo integration; statistical inference: maximum likelihood method of estimation, test of hypothesis - one

sample settings, two sample settings, analysis of variance, pairwise comparison and multiple comparison; resampling.

Introduction to MATLAB/Octave: Introduction; basic features; command window; mathematical operations in command window; array operation; matrix operations; logical operations; script m-files; function m-files; data input and output; statistical graphics: common plots in statistics, three dimensional plot, color maps, mash, and surface plots.

Programming and **Data analysis** with MATLAB/Octave.

Text Books

1. R Core Team (2012). Introduction to R (can be downloaded from http://www.cran.r-project.org).
2. Jones, O, Maillardet, R and Robinson, A (2009). Introduction to scientific programming and simulation using R. Chapman & Hall/CRC.
3. Quarteroni, A, Saleri, F and Gervasio, P (2010). Scientific computing with MATLAB and Octave, 3^{rd} *edition*. Springer.

AST 208: Mathematical Methods | **Credit 3**

Interpolation and inverse interpolation: uses of Newton's forward and backward interpolation formula; Lagrange's formula; numerical integration: Simpson's rule; Weddle's rule; trapezoidal rule; Gauss's quadratic formulae and proper examples from the applications to econometric, meteorology and biomedicine; Euler's formula of summation and quadrature.

Solution of numerical algebraic and transcendental equations; equations in one unknown; finding approximate values of the roots; finding roots by repeated application of location theorem; method of interpolation or of false position; solution by repeated plotting on a large scale; Newton-Raphson method; Newton-Raphson method for simultaneous equations.

Beta and gamma function and their properties; incomplete beta and gamma function; Dirichlet's theorem; Liouville's extension of Dirichlet's theorem.

Fourier series: periodic function; Fourier series process of determining the Fourier coefficients; Dirichlet conditions; odd and even functions; half range Fourier sine or cosine series; Parseval's identity; differentiation and integration of Fourier series.

Laplace transform: introduction; definition of integral transformation; definition of Laplace transform; Laplace transform of some elementary functions; sufficient conditions for the existence of Laplace transform; some important properties of Laplace

transform; initial and final value theorem; Laplace transforms of some special functions.

Inverse Laplace transform: definition of inverse Laplace transform; Lerch's theorem; some important properties of the inverse Laplace transform; partial function decompositions; definition of the convolution; convolution theorem; Heaviside's expansion formula; evaluation of integrals; application of Laplace transform.

Introduction to Taylor's and Laurent series.

Text Books

1. Burden, RJ and Faires, JD (2010). Numerical analysis, 9^{th} *edition*. Brooks Cole.
2. Kreyszig, E (2011). Advanced Engineering Mathematics, 10^{th} *edition*. Wiley.
3. Jeffrey, A (2001). Advanced Engineering Mathematics, 1^{st} *edition*. Academic Press.
4. Wrede, R and Speigel, MR (2010). Schaum's outline of advanced calculus, 3^{rd} *edition*. McGraw-Hill.
5. Speigel, MR (1965). Schaum's outline of Laplace transforms. McGraw-Hill.

AST 230: Statistical Computing III — **Credit 2**

Computing problems related to the courses AST 201 (Probability Distributions and Simulation) and AST 206 (Introductory Sampling Methods).

AST 231: Statistical Computing IV — **Credit 2**

Computing problems related to the courses AST 202 (Sampling Distributions and Order Statistics), AST 205 (Introduction to Demography), and AST 207 (Data Analysis using S language and MATLAB).

AST 232: Statistical Computing V — **Credit 2**

Computing problems related to the courses AST 203 (Statistical Inference I) and AST 204 (Agricultural Statistics and Design of Experiments).

AST 240: Oral II — **Credit 2**

Detailed Syllabus – Third Year

AST 301: Design and Analysis of Factorial Experiments

Credit 4

Introduction to factorial designs: basic definition and principles; advantage of factorials; two-factor factorial design; statistical analysis of fixed effects model, model adequacy checking, estimating model parameters, choice of sample size, assumption of no interaction in a two-factor model, one observation per cell; general factorial design; fitting response curve and surfaces; blocking in a factorial design.

2^k factorial design: introduction; 2^2 design; 2^3 design; general 2^k design; a single replicate in 2^k factorial design; blocking in a 2^k factorial design; confounding in 2^k factorial design; confounding in 2^k factorial design in two blocks; confounding in 2^k factorial design in four blocks; confounding in 2^k factorial design in 2^p blocks; partial confounding.

Two-level fractional factorial designs: one-half fraction of 2^k design; one-quarter fraction of 2^k design; general 2^{k-p} fractional factorial design; resolution III designs; resolution IV and V designs; three-level and mixed-level factorial and fractional factorial designs: 3^k factorial design, confounding in 3^k factorial design, fractional replication of 3^k factorial design, factorials with mixed levels.

Response surface methods: introduction to response surface methodology; method of steepest ascent; analysis of second-order response surface; experimental designs for fitting response surfaces; mixture experiments; robust designs.

Experiments with random factors: random effects model; two-factor factorial with random factors; two-factor mixed model; sample size determination with random effects; rules for expected mean squares; approximate F tests; approximate confidence intervals on variance components; modified large-sample method; maximum likelihood estimation of variance components.

Nested and split-plot designs: two-stage nested designs; statistical analysis, diagnostic checking, variance components; general m-staged nested design; designs with both nested and factorial factors; split-plot design; split-plot designs with more than two factors; split-split-plot design, strip-split-plot design.

Text Books

1. Dean, AM and Voss, AM (1999). Design and analysis of experiments. Springer.
2. Montgomery, DC (2001). Design and analysis of experiments, 5^{th} *edition.* Wiley.
3. Bailey, R (2008). Design of comparative experiments. Cambridge.

AST 302: Advanced Sampling Techniques | **Credit 3**

Sampling of unequal clusters with unequal probability with and without replacement different selection methods: PPS selection, Brewer's, Durbin's, Samford's, PPS systematic, Raj's, Murthy's and Rao-Hartley-Cochran methods of selection; detailed study on the related formulae, estimates, variances, estimates of variances for these methods.

Two-stage sampling with equal and unequal sized clusters-estimates and standard errors; estimation for proportions; stratified two-stage sampling.

Multistage sampling: different two and three stage sampling schemes; the concept of self-weighting estimates; assumptions for self-weighting estimates; sampling schemes resulting in self-weighting estimates.

Multiphase sampling: reasons for adopting this technique; two-phase or double sampling; ratio and regression estimators for double sampling and respective standard errors; double sampling for stratification; repeated sampling; sampling from the same population on two occasion, more than two occasions; Interpenetrating subsampling. Concept of base line survey and panel survey.

Sampling and non-sampling errors: sources and types of non-sampling error; non-sampling bias; non-response error; control of non-response; techniques for adjustments of non-response; Politz-Simon's technique; response bias and response variance; role of design and model in sampling: design unbiasedness; model unbiasedness.

Special sampling schemes: inverse sampling; capture-recapture method; network sampling; snowball sampling; adaptive cluster sampling; rank set sampling.

Resampling methodologies: bootstrap, jackknife and Gibbs sampling.

Text Books

1. Cochran, WG (1977). Sampling techniques, 3^{rd} *edition.* Wiley.
2. Lohr, SL (1998). Sampling: design and analysis. Duxbury.

AST 303: Applied Regression Analysis | **Credit 4**

Fitting a straight line by least squares: straight line relationship between two variables, linear regression, analysis of variance, confidence intervals and tests for intercept and regression coefficients, F-test for significance of regression.

Checking the straight line fit: lack of fit and pure error, testing homogeneity of pure error, basic plots for examining residuals, non-normality checks on residuals, checks for time effects, non-constant variance, need for transformation and curvature, Durbin-Watson tests.

Linear regression in matrix terms: fitting a straight line in matrix terms, singularity of $\mathbf{X}'\mathbf{X}$ matrix, analysis of variance in matrix terms, variances of intercept and regression coefficients from the matrix calculation, variance of predicted respone using matrix development, the general regression situation, least square properties, confidence intervals versus regions.

Extra sum of squares and tests for several parameters being zero: the extra sum of square principle, sum of squares of a set of linear functions; more on checking fitted models: the hat matrix and various types of residuals, PRESS, detection of influential observations - Cook's statistics; special topics on multiple linear regression: testing a general linear hypothesis, generalized least squares and weighted least squares, restricted least squares; selecting the "best" regression equation: all possible regression and "best subset" regression, stepwise regression, backward elimination, significance levels for selection procedures; ill-conditioning in regression data: centering regression data, centering and scaling regression data, detecting and measuring multicollinearity; ridge regression: basic form of ridge regression.

Text Books

1. Draper, NR and Smith, H (1999). Applied regression analysis, 3^{rd} *edition.* Wiley.

AST 304: Epidemiology | **Credit 3**

Concepts of epidemiology; strategy of epidemiology: disease, health and public health; natural history of disease; causal concepts; epidemiologic variables: person, place and time.

Methods of epidemiologic research: epidemiologic research; etiologic research; types of epidemiologic research; experiments, quasi-experiments, observational studies;

design options of observational studies; subject selection, methods of observations; typology of observational study designs; basic designs, hybrid designs, incomplete designs; measures of disease frequency: basic incidence measures; risk and rate; estimation of average rates; estimation of risk; prevalence measures; mortality measures; measures of association: ratio measures; difference measures; measures of potential impact; summary of epidemiologic measures.

Validity of epidemiologic research: validity and precision; internal validity; direction of bias; classification of bias; selection bias; direction, examples; information bias; examples of misclassification in only the outcome variable, general formulation of misclassification bias, independent misclassification of both exposure and disease; confounding; working definition of a confounder, risk factors, single risk factor confounding; confounding involving several risk factors; definition of joint confounding, variable selection and control of confounding.

Principles and procedures of epidemiologic analysis: statistical inferences about effect measures; hypothesis testing procedures, confidence interval procedures; control for extraneous factors; definition of controls, reasons for controls, options for controls; stratified analysis; testing for overall association, point estimation of overall association, interval estimation of effect, extension to several exposure categories; matching in epidemiologic research; definition and types of matching, advantages and disadvantages of category matching, R-to-1 matching; interaction, effect modification, and synergism; synergism, statistical interaction and effect modification.

Evaluation of disease diagnosis and screening: sensitivity, specificity, positive and negative predictive values; and receiver operating characteristic (ROC) curves.

Text Books

1. Kleinbaum, DG, Kupper, LL and Morgenstern, H (1982). Epidemiologic research. Van Nostrand Reinhold.

AST 305: Population Studies | **Credit 3**

Adjustment of demographic data: sources and types of errors and deficiencies in data; general methods of evaluation and detection of error and deficiencies in data; methods of checking completeness and other types of errors in demographic data and their adjustment.

Graduation of data: meaning and its need, techniques of graduation, graduation of age distribution; life table: its concept, structure and calculation, complete life table (life table by single year of age) and abridged life table, multiple decrement life

tables, working life table, different life table functions and inter-relationships among them, use of life table, etc.

Force of mortality: idea and definition calculation of life table with the help of force of mortality.

Population growth, techniques to measure it, doubling time concept in demography; population estimates and projections; different techniques of population projection- component method, arithmetic/linear method, geometric method, exponential method, matrix method, etc, need of population projections.

Stable and stationary population, their characteristics and uses; Lotka's characteristics equation, intrinsic birth and death rates, effect of uniform drop in force of mortality on the growth rate, effects of changes in fertility and mortality on the age distribution of population.

Model life tables, Coale and Demeny regional model life tables.

Population in Bangladesh: history of growth of population in Bangladesh; implications of the growth of population in Bangladesh; population policy in Bangladesh; level, trends and determinants in fertility, mortality and migration in Bangladesh; interrelationship between population and development; future prospects of population and population control in Bangladesh; aged and aging of population in Bangladesh.

Text Books

1. Shryock, S and others (1975). The methods and materials of demography, volume I and II. U.S. Department of Commerce Publication.
2. Bogue, DJ (1969). Principles of demography. Wiley.

AST 306: Social Statistics and Social Development

Credit 3

National income: concepts, measurement and problems; social accounting matrix; income distribution and wealth: causes of concentration; meaning of inequality; measures of inequality; frequency of income; Lorenz curve of income; Gini coefficient; Atkinson's index, etc.

Poverty: conceptual issues of poverty; measurement of different poverty indices.

Introduction to psychometrics: measurement in psychology and education; intelligent and achievement tests; test scores; equivalence of scores; Z-score and T-score; intelligent quotient.

Definition, nature and importance of anthropology; role and functions of family.

Social inequality: inequality by sex, age, rank, caste, race, class, power, rule and social connections.

Social sector development policies: development in agriculture, industry (a) growth performance, outlay and yield (b) agrarian structure and its changes (c) plan outlay; rural development; human development; women and youth development; land reforms in Bangladesh; infrastructure development; ADP allocation to social sectors; fiscal policies for development.

Text Books

1. Atkinson, AB (1978). The economics of inequality. Clarendon Press.
2. Atkinson, AB (1980). Wealth, income and inequality.

AST 307: Research Planning, Monitoring and Evaluation

Credit 3

Concept, aims and objectives of research; types of research; steps involved in research; selection and formulation of research problems; proposal writing; examining the designs of some known researches.

Questionnaire, check lists, FGD guidelines etc; preparation of questionnaires; preparation of manuals for interviewer; enumerators training, monitoring and supervision for controlling the quality of data; how to avoid non-response.

Report writing; content and organizations of the report; heading and subheadings; techniques of writing conclusion, summary, recommendations, footnotes references, appendix, etc; examining some local and international reports.

Concept of monitoring and evaluation (M & E): objectives, usefulness and scope of M & E; views of different schools on M & E; performance monitoring versus performance evaluation.

Timing and type of M & E: summative, formative, continuous, participatory, diagnostic, logframe, etc; baseline, ongoing and end line evaluation; impact evaluation; M & E of ongoing programs (activities, inputs, outputs, effect); follow-up for remedies, and post-programs evaluation.

Monitoring and evaluation plan and data sources: indicators for monitoring and evaluation; identification of indicators and characteristics of ideal indicators; factors influencing indicator selection; implementing monitoring and evaluation exercise: data sources and tools: surveys, questionnaires, checklists, etc; quality control; setting up and developing low cost M & E and documentation.

Application: monitoring and evaluation in population, health, nutrition, and other socio-economic programs relating to education, industry and parity.

Text Books

1. Blankenberg, F (1993). Introduction into the planning, monitoring and evaluation system, April, Dhaka.
2. Bhola, S (1990). Evaluating literacy for development, projects, programs and campaigns. UIE and DSE, UIE Handbook and Reference Book 3, Hamburg.

AST 308: Data Analysis using SPSS, SAS, and Stata

Credit 3

SPSS

Introduction to SPSS: meaning, application and background of SPSS; reading the data set: reading SPSS data, reading data from spreadsheet formats, reading data from simple database formats, reading data from other statistical programs, e.g, Stata, SAS, etc; defining the variable: variable type, variable name, variable formats, variable labels, value labels; transformation expressions: numeric expressions, arithmetic operations, numeric functions, arithmetic functions, statistical functions, random variable and distribution functions, missing values in numeric expressions, logical expressions, logical functions, relational operators, not logical operator, AND and OR logical operators, other functions; working with date and time: date and time formats, arithmetic operations with date and time variables, date and time functions; working with commands: introduction, syntax diagrams, command specification, running commands, subcommands, keywords, delimiters, command order; different commands in SPSS: get, save, save outfile, split files, sort cases, add files, match files, import, compute, recode, if, select if, do if, end if, list, aggregate, sample selection, report; graphical presentation: simple bar graphs, line graphs, graphs for cumulating frequency and pie graphs; statistical analysis: univariate analysis - frequencies, descriptive statistics, multiple response, bivariate analysis - crosstabs, correlation; means; statistical tests (parametric and non-parametric); anova; regression; logistic regression.

SAS

Introduction to SAS: overview of the SAS data step, syntax of SAS procedures, comment statements; reading the data set, external files (reading and writing raw

and system files): data in the program itself, reading ascii data from an external file, infile options, writing ascii or raw data to an external file, creating and reading a permanent data sets, defining the variable: variable type, variable name, variable formats, variable labels, value labels, writing with large data sets, data set subsetting, concatenating, merging and updating; working with arrays; restructuring SAS data sets using arrays, describing data: describing data, more descriptive statistics, frequency distributions, bar graph and plotting data, creating summary data sets with proc means and proc univariate, outputting statistics other than means; analyzing categorical data: questionnaire design and analysis, adding variable and value labels, recoding data, two-way and multiple tables; working with date and longitudinal data: processing date variables, longitudinal data; SAS procedures: correlation and regression, t-tests and non-parametric comparisons, analysis of variance, repeated measures designs, multiple regression analysis, logistic regression.

Stata

Introduction to Stata: an example of Stata session, documentation and help files, searching for information; data management: example commands, creating a new data set, specifying subsets of data with in and if qualifiers, generating and replacing variables, using functions, converting numeric and string formats, creating new categorical and ordinal variables, importing data from other programs, combining Stata files, transporting, reshaping or collapsing data, weighting observations, creating random data and random samples, managing memory; graphs: example commands, histograms, scatterplots, line plots, connected-line plots, other two-way plots, box plots, pie and bar charts, retrieving and combining graphs; summary statistics and tables: example commands, summary statistics for measurement variables, exploratory data analysis, normality tests and transformations, frequency tables and two-way cross tabulations, multiple tables and multi-way cross tabulations, tables of means, medians and other summary statistics; anova and other comparison methods: example commands, one-sample tests, two-sample tests, one-way and two-way analysis of variance, analysis of covariance (ancova); linear regression analysis: example commands, regression table, multiple regression, predicted values and residuals, basic graphs for regression, correlations, hypothesis tests, dummy variables, categorical variables and interactions, stepwise regression, polynomial regression; regression diagnostics: example commands, diagnostic plots, diagnostic case statistics; introduction to programming: basic concepts and tools, matrix algebra, bootstrapping and Monte Carlo simulation.

Text Books

1. Cody, RP and Smith, JK (2005). Applied statistics and the SAS programming language, 5^{th} *edition*. Prentice Hall.
2. Norusis, MJ (1988). SPSS/PC for the IBM PC/XT/AT.
3. Hamilton, L. C. (2006), Statistics with Stata, Thomson Brooks/Cole.

AST 309: Mathematical Analysis **Credit 4**

The real number system; axioms and completeness and its consequences; Dedekind cut, sets, compact sets; simple operation on them.

Sequence of functions of one and several variables; limit; continuity; continuous functions; uniform continuity; differentiation and integration; infinite series of constants and functions; convergence and divergence; power series: differentiation and integration of power series; Taylor expansion with remainder or in infinite series.

Metric and topological spaces; limit points; open and closed sets; interior and exterior points; boundary points; continuous mapping and Cauchy sequences.

Measure and integrals on abstract sets on real lines; Cramer measurability: fundamental definitions; auxiliary lemma; fundamental theorems; measurable functions; Lebesgue measure on a real line, plane; integrals; Riemann-Steiljes integrals.

Text Books

1. Rudin, W (1976). Principles of mathematical analysis. McGraw-Hill.

AST 330: Statistical Computing VI **Credit 2**

Computing problems related to the courses AST 301 (Design and Analysis of Factorial Experiments) and AST 304 (Epidemiology).

AST 331: Statistical Computing VII **Credit 2**

Computing problems related to the courses AST 302 (Advanced Sampling Techniques), AST 306 (Social Statistics and Social Development), and AST 308 (Data Analysis using SPSS and SAS).

AST 332: Statistical Computing VIII | **Credit 2**

Computing problems related to the courses AST 303 (Applied Regression Analysis) and AST 305 (Population Studies).

AST 340: Oral III | **Credit 2**

Detailed Syllabus – Fourth Year

AST 401: Advanced Probability and Stochastic Processes

Credit 3

Modern probability: events as sets, field, sigma field, probability measure, Borel field and extension of probability measure, measure theoretic approach of random variables; probability space; probability mass function, probability density function, distribution function, expectations and moments, generating functions.

Convergence of random variables: modes of convergence: almost sure, rth mean, in probability, in distribution, their interrelationship; law of large numbers, strong and weak laws of large numbers, limiting distribution; central limit theorem; law of iterated logarithm; martingale.

Markov chains: introduction, Chapman-Kolmogorov equations, classification of states, limiting probabilities, gamblers ruin problem, mean time spent in transient states, branching processes, time reversible Markov chains, Markov chain Monte Carlo methods, Markov decision processes, hidden Markov chains.

Poisson process: exponential distribution, properties, convolutions of exponential random variables; counting processes, Poisson process, interarrival and waiting time distributions, further properties of Poisson processes, generalizations of the Poisson process, nonhomogeneous Poisson process, compound Poisson process, conditional or mixed Poisson processes.

Continuous-time Markov chains: introduction, continuous-time Markov chains, birth and death processes, transition probability function, limiting probabilities, time reversibility.

Renewal theory and its applications : introduction, distribution of renewals, limit theorems and their applications, renewal reward processes, regenerative processes, semi–Markov processes, Markov renewal processes.

Text Books

1. Grimmett, G and Stirzaker, D (2001). Probability and random processes, 3^{rd} *edition.* Oxford University Press, USA.
2. Ross, S (2010). Introduction to probability models, 10^{th} *edition.* Elsevier.

AST 402: Statistical Inference II | **Credit 4**

Statistical inference: parametric, nonparametric and semiparametric inference; principles of data reduction: sufficiency principle, likelihood principle, equivariance principle; maximum likelihood (ML) method of estimation: likelihood function, ML estimators, expected values and bias, standard errors; restricted maximum likelihood (REML) method of estimation; profile likelihood function; Bayesian method of estimation: prior and posterior distribution, different types of prior; confidence intervals and hypothesis testing: generalized likelihood ratio test, Bayesian hypothesis testing, credible interval; inference based on missing data: introduction, EM algorithm; comparison of estimators: decision theoretic approach - loss function and risk function, robustness - M estimators; method of evaluating tests.

Nonparametric inference: introduction, inference concerning cumulative distribution function (cdf), quantiles and statistical functionals: empirical cdf, quantiles, estimating statistical functionals, influence functions, testing statistical hypothesis - one sample settings, two or more sample settings; tolerance limit; resampling - bootstrap and jackknife and their uses, parametric bootstrap, bootstrap confidence intervals; empirical density estimation: histograms, kernel, kernel density estimation, local polynomials, multivariate problems; converting density estimation into regression; nonparametric regression: smoothers, linear smoothers, choosing smoothing parameter; local regression - loess and lowess, penalized regression, splines; confidence bands; average coverage; summary of linear smoothing; local likelihood and exponential families.

Text Books

1. Casella, G and Berger, RL (2002). Statistical inference, 2^{nd} *edition.* Duxbery.
2. Wasserman L. (2006). All of nonparametric statistics. Springer.

AST 403: Applied Multivariate Data Analysis | **Credit 3**

Preliminaries of multivariate analysis: applications of multivariate techniques; the organization of data; data display and pictorial representations; distance.

Random vectors and random sampling: some basic of matrix and vector algebra; positive definite matrices; a square-root matrix; random vectors and matrices; mean vectors and covariance matrices; matrix inequalities and maximization; the geometry of the sample; random sample and expected values of sample means and covariance

matrix; generalized variance; sample mean, covariance, and correlation as matrix operations; sample values of linear combinations of variables.

The multivariate normal distribution: the multivariate normal density and its properties; sampling from a multivariate normal distribution and maximum likelihood estimation; sampling distribution and large sample behavior of sample mean vector and sample variance-covariance matrix; assessing the assumption of normality; detecting outliers and data cleaning; transformation to near normality.

Inferences about a mean vector: the plausibility of mean vector as a value for a normal population mean; Hotelling T^2 and likelihood ratio tests; confidence regions and simultaneous comparisons of component means; large sample inference about a population mean vector; inferences about mean vectors when some observations are missing; time dependence in multivariate data.

Comparisons of several multivariate means: paired comparisons and a repeated measures design; comparing mean vectors from two populations; comparison of several multivariate population means (one-way MANOVA); simultaneous confidence intervals for treatment effects; two-way multivariate analysis of variance; profiles analysis; repeated measures designs and growth curves;

Multivariate linear regression models: the classical linear regression model; least squares estimation; inferences about regression model; inferences from the estimated regression function; model checking; multivariate multiple regression; comparing two formulations of the regression model; multiple regression model with time dependent errors.

Text Books

1. Johnson, RA and Wichern, DW (1999). Applied multivariate statistical analysis, 4^{th} *edition*. Prentice-Hall.
2. Srivastava, MS (2002). Methods of multivariate statistics. Wiley.

AST 404: Econometric Methods | **Credit 3**

Relaxing the assumptions of the classical model: multicollinearity, nature of multicollinearity; estimation in the presence of multicollinearity; practical consequences of multicollinearity; detection of multicollinearity; remedial measures; heteroscedasticity: nature of heteroscedasticity; method of generalized least squares; consequences using ordinary least squares in the presence of heteroscedasticity; detection of heteroscedasticity; remedial measures; autocorrelation: nature of the problem; OLS

estimation in the presence of autocorrelation; the BLUE estimator in the presence of autocorrelation; consequences of using OLS in the presence of autocorrelation; detection of autocorrelation; remedial measures; autoregressive conditional heteroscedasticity (ARCH) model.

Econometric modeling: average economic regression (AER); types and consequences of specification errors; tests of specification errors; errors of measurement; model selection - Leamer's approach, Hendry's approach; diagnostic tests, tests of non-nested hypothesis.

Regression models for dummy variables: models for one quantitative and one qualitative variables, one quantitative and two qualitative variables; comparing two regressions - dummy variable approach; interaction effects; use of dummy variables in seasonal analysis; piecewise linear regression; regression on dummy dependent variables; linear probability model; the logit model; the probit model; the tobit model.

Dynamic econometric model: the role of "time" or "lag" in econometrics; the Koyck approach to distributed-lagmodels; estimation of autoregressive models; the method of instrumental variables; detecting autocorrelation in autoregressive models - Durbin h test; the Almon approach to distributed lag models; the identification problem: endogeneity and exogeneity, simultaneous equation model: the nature of simultaneous equation model; simultaneous equation bias; identification problem; rules for identification; a test for simultaneity; a test for exogeneity; simultaneous-equation methods; recessive models and ordinary least squares; method of indirect least squares (ILS); method of two-stage least squares (2SLS).

Text Books

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

AST 405: Lifetime Data Analysis | **Credit 4**

Basic concepts and models: lifetime distributions - continuous models, discrete models, a general formulation; some important models - exponential, Weibull, log-normal, log-logistic, gamma distributions, log-location-scale models, inverse Gaussian distributions re models, mixture; Regression models.

Observation schemes, censoring, and likelihood: right censoring and maximum likelihood; other forms of incomplete data; truncation and selection effects; information and design issues.

Nonparametric and graphical procedures: nonparametric estimation of survivor function and quantiles; descriptive and diagnostic plots; estimation of hazard or density functions; methods of truncated and interval censored data; life tables.

Inference procedures for parametric models: inference procedures for exponential distributions; gamma distributions; inverse Gaussian distributions; grouped, interval censored, or truncated data; mixture models; threshold parameters; prediction intervals.

Inference procedure for log-location-scale distributions: inference for location-scale distributions; Weibull and extreme-value distributions; log-normal and log-logistic distributions; comparison of distributions; models with additional shape parameters; planning experiment for life tests.

Parametric regression models: introduction to log-location-scale regression models, proportional hazards regression models; graphical methods and model assessment; inference for log-location-scale models; extensions of log-location-scale models; hazard based models.

Text Books

1. Lawless, J (2003). Statistical models and methods for lifetime data, 2^{nd} *edition.* Wiley.
2. Kalbfleisch, J and Prentice, R (2003). The statistical analysis of failure time data, 2^{nd} *edition.* Wiley.

AST 406: Industrial Statistics and Operations Research

Credit 3

Industrial Statistics

Fundamental concepts of industrial statistics and its purposes; industrial quality control: total quality control; statistical quality control; chance and assignable causes of variation; statistical process control.

Control chart: concept of control chart; statistical basis of the control chart; basic principles; choice of control limits; sample size and sampling frequency; rational subgroups; analysis of patterns on control charts; sensitizing rules for control charts; necessary steps for constructing control charts; types of control charts (control charts

with standard given and control charts with no standard given); control charts for attributes: concepts of nonconformity; nonconforming unit; defect; defective unit; p-chart; d-chart; c-chart; u-chart; basic concepts of control charts for variables; statistical basis and interpretation of, R and S charts.

Acceptance sampling: basic concepts of acceptance sampling; OC curve and its uses; types of OC curves; properties of OC curves. Single sampling plan: basic concepts of single sampling plan for attributes; construction of type A and type B OC curves under single sampling plan for attributes; specific points on the OC curve (AQL, LTPD); rectifying inspection; AOQ; AOQL; ATI; ASN; designing a single sampling plan; double sampling plan: basic concepts of double sampling plan; OC curve; ASN: AOQ; ATI; designing a double sampling plan; introduction to multiple sampling plan and sequential sampling analysis; acceptance sampling plan by variables: basic concepts of acceptance sampling plan; types of sampling plans; designing a variable sampling plan with a specified OC curve.

Operations Research

Nature and impact of OR approach; phases of OR; concept of linear programming problem (LPP); construction of LPP; solution of LPP: graphical and the simplex method; revised simplex method; big-M method, two phase method; concept of convergence, degeneracy and cycling; duality: dual primal relationship and formulation of dual problems; sensitivity analysis: introduction to sensitivity analysis; game theory: finite and infinite games; zero sum games; two person zero sum games; pay off matrix; maximum and minimum criterion of optimal solution of a game; dominance property; algebraic method for the solution of a game; equivalence of rectangular game matrix and linear programming; application in real life situation using MATLAB/Octave software.

Text Books

1. Montgomery, DC (2004). Introduction to statistical quality control. Wiley.
2. Hillier, FS, Lieberman, GJ, Nag, B and Basu P (2001). Introduction to operations research, 9^{th} *edition.* McGraw-Hill.

AST 407: Actuarial Statistics | **Credit 3**

The meaning of actuarial science; role of insurance in the economy; role of an actuary.

Fundamentals of theory of interest: de

nition of simple interest and compound interest and their comparisons; accumulated value factors and present value factors; effective and nominal rates of interest and

their interrelationship; effective and nominal rates of discount; relation between interest and discount; equations of value and use of the time diagram in solutions of problems in interest; problems involving unknown length of investment and unknown rate of interest; annuity; different types of annuities certain; present and accumulated values of immediate annuity and annuity due; present value of deferred annuities and variable annuities; capital redemption policies; amortization schedules and sinking funds.

Actuarial mathematics: discrete life annuity and its applications; present values of different life annuities; life assurance; present values of various life assurances in terms of commutation functions; related problems; Premiums; Different types of premiums; Net premiums; Office premiums; Prospective policy values.

The basic deterministic model: Cash flows; An analogy with currencies; Discount functions; Calculating the discount function; Interest and discount rates; Constant interest; Values and actuarial equivalence; Regular pattern cash flows; Balances and reserves; Basic concepts; Relationship between balances and reserves.

Stochastic interest-rate models: Stochastic interest-rate models I; Basic model for one stochastic interest rate; Independent interest rates; Stochastic interest-rate models II; Dependent annual interest rates; Modelling the force of interest; What can one do with these models.

Text Books

1. Kellison, SG (1991). The theory of interest, 2^{nd} *edition.* McGraw-Hill/Irwin.
2. Promislow, SD (2011). Fundamentals of actuarial mathematics, 2^{nd} *edition.* John Wiley & Sons.

AST 408: Modeling Time Series Data | **Credit 3**

Introduction: examples of time series, objectives of time series analysis; simple descriptive techniques: types of variation, stationary time series, the time plot, transformations, analyzing series which contain a trend, analyzing series which contain seasonal variation, autocorrelation, other tests of randomness; time series models: estimating autoregressive and autocorrelation functions, fitting an autoregressive process, fitting a moving average process, estimating parameters of an ARMA model, estimating parameter of an ARIMA model, box-jenkins seasonal ARIMA models, residual analysis, general remarks on model building; forecasting: introduction, univariate procedures, multivariate procedures, comparative review of forecasting procedures, prediction theory.

Text Books

1. Makridakis, S, Wheelwright, C and Hyndman, RJ (1997). Forecasting: methods and applications, 3^{rd} *edition*. Wiley.
2. Chatfield, C (2003). The analysis of time series, 6^{th} *edition*. Chapman & Hall.

AST 409: Generalized Linear Models **Credit 3**

Generalized linear models: exponential family of distributions; estimation: method of maximum likelihood, method of least squares, estimation of generalized linear models; inference: sampling distribution for scores, sampling distribution for maximum likelihood estimators, confidence intervals for model parameters, adequacy of a model, sampling distribution for log-likelihood statistic, log-likelihood ratio statistic (deviance), assessing goodness of fit, hypothesis testing; multiple regression: maximum likelihood estimation, log-likelihood ratio statistic.

Models for binary responses: probability distributions, generalized linear models, dose response models, general logistic regression, maximum likelihood estimation and log-likelihood ratio statistic, other criteria for goodness of fit, least square methods; multinomial distributions; nominal logistic regression models; ordinal logistic regression models.

Models for count data, Poisson regression and log-linear models: probability distributions, maximum likelihood estimation, hypothesis testing and goodness of fit.

Text Books

1. Dobson, A (2008). An introduction to generalized linear models, 3^{rd} *edition*. Chapman & Hall. .

AST 430: Statistical Computing IX **Credit 2**

Computing problems related to the courses AST 401 (Advanced Probability and Stochastic Processes), AST 402 (Statistical Inference II), and AST 405 (Lifetime Data Analysis).

AST 431: Statistical Computing X **Credit 2**

Computing problems related to the courses AST 403 (Applied Multivariate Data Analysis), AST 404 (Econometric Methods), and AST 408 (Modeling Time Series Data).

AST 432: Statistical Computing XI **Credit 2**

Computing problems related to the courses AST 406 (Industrial Statistics and Operations Research), AST 407 (Actuarial Statistics), and AST 409 (Generalized Linear Models).

AST 440: Oral IV **Credit 2**

AST 450: Project and Seminar **Credit 3**

Each student will be required to prepare a project report and present the report in a seminar. For the project work, each student will be assigned to a teacher at the beginning of the academic year. Submission and evaluation should be made before the commencement of final examination. Fifty percent weight of the course will be allotted to project works and the remaining fifty percent will be for seminar presentation. The internal members of the examination committee will evaluate the performance in the seminars and the report will be evaluated by two internal examiners nominated by the examination committee. A supervisor cannot evaluate a project s/he has supervised.
