

Choice Based Credit System in B.Sc. In Statistics (Regular Course)

Semester	Core Course (12)	Ability Enhancement Compulsory Course (AECC) (2)	Skill Enhancement Elective Course (SEC)(2)	Discipline Specific Elective DES(6)
I	Differential Calculus	AECC1		
	Statistical Methods			
	Linear Programming			
II	Differential Equations	AECC2		
	Descriptive Statistics and Probability Theory			
	Mathematical Programming		SEC 1	
III	Real Analysis			
	Statistical Inference			
	Inventory Systems & Marketing Management			
IV	Algebra		SEC 2	
	Sample Surveys and Design of Experiments			
	Network Analysis & Theory of Sequencing			
V			SEC 3	DSE 1A
				DSE 2A
				DSE 3A
VI			SEC 4	DSE 1B
				DSE 2B
				DSE 3B

Core 1.1: Differential Calculus

Limit and Continuity (ϵ and δ definition), Types of discontinuities, Differentiability of functions, Successive differentiation, Leibnitz's theorem, Partial differentiation, Euler's theorem on homogeneous functions.

Tangents and normals, Curvature, Asymptotes, Singular points, Tracing of curves. Parametric representation of curves and tracing of parametric curves, Polar coordinates and tracing of curves in polar coordinates.

Rolle's theorem, Mean Value theorems, Taylor's theorem with Lagrange's and Cauchy's forms of remainder, Taylor's series, Maclaurin's series of $\sin x$, $\cos x$, e^x , $\log(l+x)$, $(1+x)^m$, Maxima and Minima, Indeterminate forms.

Books Recommended

1. H. Anton, I. Birens and S. Davis, *Calculus*, John Wiley and Sons, Inc., 2002.
2. G.B. Thomas and R.L. Finney, *Calculus*, Pearson Education, 2007.

Core 1.2: Statistical Methods

Random variables: Discrete and continuous random variables, p.m.f., p.d.f. and c.d.f., illustrations of random variables and its properties, expectation of random variable and its properties. Moments and cumulants, moment generating function, cumulants generating function and characteristic function. Probability generating function, Transformation in univariate and bivariate distributions. Bivariate probability distributions; marginal and conditional distributions; independence of variates (only general idea to be given).

Point (or degenerate), binomial, Poisson, Geometric, negative binomial, Hypergeometric Normal, Uniform, Exponential, Beta and Gamma distributions.

Statement and application of Chebychev's inequality, WLLN and SLLN, Central limit theorem (CLT) for I.i.d. variates, and its applications. De Moivre's Laplace Theorem.

Books Recommended

1. A.M. Goon, M.K. Gupta and B. Dasgupta, *An outline of Statistical Theory* (Vol. I), 4th Ed., World Press, Kolkata, 2003.
2. S.C. Gupta and V.K. Kapoor, *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand and Sons, 2007.
3. R.V. Hogg, A.T. Craig, and J.W. McKean, *Introduction to Mathematical Statistics*, 6th Ed. Pearson Education, 2005.
4. A.M. Mood, F.A. Graybill and D.C. Boes, *Introduction to the Theory of Statistics*, 3rd Ed., Tata McGraw Hill Publication, 2007.
5. V.K. Rohtagi and A.K. Md. E. Saleh, *An Introduction to Probability and Statistics*, 2nd Edition, John Wiley and Sons, 2009.
6. S.A. Ross, *Introduction to Probability Models*, 9th Ed., Academic Press, 2007.

Core 1.3: Linear Programming

Introduction to Operational Research and overview of O.R. modeling. Linear independence and dependence. Convex sets. Extreme points. Hyperplanes and Polyhedral sets. Solution of a System of Linear Equations, Concept of Basis, Basis Feasible Solutions.

Introduction to Linear Programming Problem. Problem formulations. Graphical solution.

Theory of Simplex method. Two Phase Simplex method. M-charne's simplex method. Duality in Linear Programming, Economic interpretation of duality.

Assignment problem. Transportation problem and its mathematical formulation, northwestcorner method least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem.

Books Recommended

1. G. Hadley, *Linear Programming*, Narosa, 2002.
2. Hamdy A. Taha, *Operations Research- An Introduction*, Prentice Hall, 8th edition, 2007.
3. F.S. Hillier, G.J. Lieberman, *Introduction to operations research- Concepts and Cases*, 9th Edition, Tata McGraw Hill, 2010.

Core 2.1: Differential Equations

First order exact differential equations. Integrating factors, rules to find an integrating factor.

First order higher degree equations solvable for x, y, p. Methods for solving higher-order differential equations. Basic theory of linear differential equations, Wronskian, and its properties. Solving a differential equation by reducing its order.

Linear homogenous equations with constant coefficients, Linear non-homogenous equations, The method of variation of parameters, The Cauchy-Euler equation, Simultaneous differential equations, Total differential equations.

Order and degree of partial differential equations, Concept of linear and non-linear partial differential equations, Formation of first order partial differential equations, Linear partial differential equation of first order, Lagrange's method, Charpit's method.

Classification of second order partial differential equations into elliptic, parabolic and hyperbolic through illustrations only.

Books Recommended

1. Shepley L. Ross, *Differential Equations*, 3rd Ed., John Wiley and Sons, 1984.
2. I. Sneddon, *Elements of Partial Differential Equations*, McGraw-Hill, International Edition, 1967.

Core 2.2: Descriptive Statistics and Probability Theory

Concepts of a statistical population and sample from a population, quantitative and qualitative data, nominal, ordinal and time-series data, discrete and continuous data. Presentation of data by tables and by diagrams, frequency distributions for discrete and continuous data, graphical representation of a frequency distribution by histogram and frequency polygon, cumulative frequency distributions (inclusive and exclusive methods). Measures of location (or central tendency) and dispersion, moments, measures of skewness and kurtosis, cumulants. Bivariate data: Scatter diagram, principle of least-square and fitting of polynomials and exponential curves. Correlation and regression. Karl Pearson coefficient of correlation, Lines of regression,

Spearman's rank correlation coefficient, multiple and partial correlations (for 3 variates only). Random experiment, sample point and sample space, event, algebra of events, Definition of Probability - classical, relative frequency and axiomatic approaches to probability, merits and demerits of these approaches (only general ideas to be given). Addition theorem, Theorem on conditional probability, independent events. Baye's theorem and its applications.

Books Recommended

1. J.E. Freund, *Mathematical Statistics with Applications*, 7th Ed., Pearson Education, 2009.
2. A.M. Goon, M.K. Gupta and B. Dasgupta, *Fundamentals of Statistics*, Vol. I, 8th Ed., World Press, Kolkatta, 2005.
3. S.C. Gupta and V.K. Kapoor, *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand and Sons, 2007.
4. R.V. Hogg, A.T. Craig and J.W. McKean, *Introduction to Mathematical Statistics*, 6th Ed., Pearson Education, 2005.
5. A.M. Mood, F.A. Graybill and D.C. Boes, *Introduction to the Theory of Statistics*, 3rd Ed., Tata McGraw Hill Publication, 2007.

Core 2.3: Mathematical Programming

Unconstrained and constrained optimization problems. Types of extrema and their necessary and sufficient conditions.

Convex functions and their properties. Kuhn-Tucker optimality conditions. Quadratic Programming. Wolfe's Method.

Books Recommended

1. Hamdy A. Taha, *Operation research-An Introduction*, Prentice Hall, 8th Ed., 2007.
2. Wayne L. Winston and M. Venkataramanana, *Introduction to Mathematical Programming: Applications and Algorithm*, 4th Ed., Duxbury Press, 2002.
3. S. Chandra, Jayadeva, Aparna Mehra, *Numerical Optimization with Applications*, Narosa Publication House, 2009.
4. A. Ravindran, D.T. Phillips and James J. Solberg, *Operations Research-Principles and Practice*, John Wiley and Sons, 2005.

Core 3.1: Real Analysis

Finite and infinite sets, examples of countable and uncountable sets. Real line, bounded sets, suprema and infima, completeness property of \mathbb{R} , Archimedean property of \mathbb{R} , intervals. Concept of cluster points and statement of Bolzano-Weierstrass theorem.

Real Sequence, Bounded sequence, Cauchy convergence criterion for sequences. Cauchy's theorem on limits, order preservation and squeeze theorem, monotone sequences and their convergence (monotone convergence theorem without proof).

Infinite series. Cauchy convergence criterion for series, positive term series, geometric series, comparison test, convergence of p-series, Root test, Ratio test, alternating series, Leibnitz's test (Tests of Convergence without proof). Definition and examples of absolute and conditional convergence.

Sequences and series of functions, Pointwise and uniform convergence. M_n -test, M-test, Statements of the results about uniform convergence and integrability and differentiability of functions, Power series and radius of convergence.

Books Recommended

1. T.M. Apostol, *Calculus* (Vol. I), John Wiley and Sons (Asia) P. Ltd., 2002.
2. R.G. Bartle and D. R Sherbert, *Introduction to Real Analysis*, John Wiley and Sons (Asia) P. Ltd., 2000.
3. E. Fischer, *Intermediate Real Analysis*, Springer Verlag, 1983.
4. K.A. Ross, *Elementary Analysis- The Theory of Calculus Series-* Undergraduate Texts in Mathematics, Springer Verlag, 2003.

Core 3.2: Statistical Inference

Estimation: Parameter space, sample space, point estimation, requirement of a good estimator, consistency, unbiasedness, efficiency, sufficiency, Minimum variance unbiased estimators. Cramer-Rao inequality (Statement only). Methods of estimation: maximum likelihood, least squares and minimum variance, moments, statement of Rao-Blackwell theorem and lehmann-Scheffe

theorem. Properties of maximum likelihood estimators (illustration). Interval Estimation: confidence intervals for the parameters of normal distribution, confidence intervals for difference of mean and for ratio of variances.

Testing of Hypothesis: Statistical Hypothesis, simple and composite hypotheses. Test of statistical hypothesis, null and alternative hypotheses. Critical region. Two kinds of errors, Level of significance and power of a test. MP test and region. Neyman-Pearson lemma (statement only). Likelihood ratio test, UMP test, UMPU test, Critical regions for simple hypothesis for one parameter.

Non-Parametric Tests: One sample and two sample sign test, Wald-Wolfowitz run test, run test for randomness, Median test and Wilcoxon-Mann-Whitney test (derivation not required, give stress on examples).

Books Recommended

1. G. Casella and R.L. Berger, *Statistical Inference*, 2nd Ed., Thomson Duxbury, 2002.
2. E.J. Dudewicz and S.N. Mishra, *Modern Mathematical Statistics*, John Wiley and Sons, 1988.
3. J.D. Gibbons and S. Chakraborty, *Non Parametric Statistical Inference*, 4th Ed., Marcel Dekkar, CRC, 2003.
4. A.M. Goon, M.K. Gupta and B. Dasgupta, *An Outline of Statistical Theory* (Vol. I), 4th Ed., World Press, Kolkata, 2003.
5. S.C. Gupta and V.K. Kapoor, *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand and Sons, 2007.
6. M.G. Kendall and A. Stuart, *The Advanced Theory of Statistics* (Vol. III), Macmillan Publishing Co., Inc., 1977.
7. R.V. Hogg, A.T. Craig and J.W. Mckean, *Introduction to Mathematical Statistics*, 6th Ed. Pearson Education, 2005.
8. V.K. Rohtagi and A.K. Md. E. Saleh, *An Introduction to Probablity and Statistics*, 2nd Ed., John Wiley and Sons, 2009.

Core 3.3: Inventory Systems and Marketing Management

Concepts and problems in Inventory Systems, classification of Inventory Systems, different costs in Inventory Systems and method of their estimation. Deterministic Inventory models with and without lead time and with and without shortages. Inventory models with all units Quality Discounts. Single period stochastic inventory models. Production scheduling problems. Concept of marketing and its role in organization. Marketing decisions, scientific marketing analysis. Uses and limitations of mathematical models in marketing, classification of market structure in competitive conditions. Demand elasticity, joint optimization of price, quality and promotional efforts. Pricing decisions, media allocation for advertisement. Brand switching analysis.

Books Recommended

1. G. Hadley, T.M. Whitin, *Analysis of Inventory Systems*, D.B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc., 1979.
2. Zipkin, *Foundations of Inventory Management*, McGraw Hall Inc., 2000.
3. Donald Waters, *Inventory Control*, John Wiley, 2003.
4. Philip Kotler, *Marketing Management*, 13th Ed., Prentice Hall of India, 2008.
5. Tony Curtis, *Marketing for Engineers, Scientists and Technologists*, John Wiley & Sons Inc., 2008.
6. Graham J. Hooley and Michael K. Hassey, *Quantitative Methods in Marketing*, 2nd Ed., International Thomson Business Press, 1999.
7. Grahame R. Dowling, *The Art and Science of Marketing –Marketing for Marketing Managers*, Oxford University press, 2005.
8. Gary L. Lilien, Philip Kotler, K. Sridhar Moorthy, *Marketing Models*, Prentice Hall of India, 2003.

Core 4.1: Algebra

Definition and examples of groups, examples of abelian and non-abelian groups, the group Z_n of integers under addition modulo n and the group $U(n)$ of units under multiplication modulo n . Cyclic groups from number systems, complex roots of unity, circle group, the general linear group $GL_n(n, R)$, groups of symmetries of (i) an isosceles triangle, (ii) an equilateral triangle, (iii) a rectangle, and (iv) a square, the permutation group $Sym(n)$, Group of quaternions. Subgroups, cyclic subgroups, the concept of a subgroup generated by a subset and the commutator subgroup of group, examples of subgroups including the center of a group. Cosets, Index of subgroup, Lagrange's theorem, order of an element, Normal subgroups: their definition, examples, and characterizations, Quotient groups. Definition and examples of rings, examples of commutative and non-commutative rings: rings from number systems, Z_n the ring of integers modulo n , ring of real quaternions, rings of matrices, polynomial rings, and rings of continuous functions. Subrings and ideals, Integral domains and fields, examples of fields: Z_p , Q , R , and C . Field of rational functions.

Books Recommended

1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002.
2. M. Artin, *Abstract Algebra*, 2nd Ed., Pearson, 2011.
3. Joseph A Gallian, *Contemporary Abstract Algebra*, Narosa, 1999.
4. George E Andrews, *Number Theory*, Hindustan Publishing Corporation, 1984.

Core 4.2: Sample Surveys and Design of Experiments

Sample Surveys: Concepts of population and sample. Complete enumeration vs. sampling. Need for sampling. Principal and organizational aspects in the conduct of a sample survey. Properties of a good estimator, Sampling and non-sampling errors. SRSWR & SRSWOR, determination of sample size. Stratified random sampling and different allocations. Systematic sampling, comparison of known sampling strategies under linear trend. Ratio and Regression estimators and their comparison with SRSWOR estimator. Indian Official Statistics: Present Official Statistical System in India relating to census of population, agriculture, industrial production, and prices; methods of collection of official statistics, their reliability and limitation and the principal publications containing such statistics. Also the various agencies responsible for the data collection- C.S.O., N.S.S.O., Office of Registrar General, their historical development, main functions and important publications. Analysis of variance and covariance: Analysis of variance and covariance (with one concomitant variable) in one-way and two-way classified data with equal number of observations per cell. Design of experiments: Principles of experimentation, uniformity trials, completely randomized, Randomized block and Latin square designs. Missing plot technique, 2^2 and 2^3 Factorial experiments: construction and analysis. Regression Analysis: Two variables linear model; estimation, testing and problems of predication. Predication of the estimated regression equation, interval estimation, estimation of variance.

Books Recommended

1. W.G. Cochran, *Sampling Techniques*, John Wiley and Sons, New York, 1997.
2. A.M. Goon, M.K. Gupta, and B. Dasgupta, *Fundamentals of Statistics* (Vol. II), 8th Ed., World Press, Kolkata, 2005.
3. A.M. Goon, M.K. Gupta and B. Dasgupta, *An Outline of Statistical Theory* (Vol. II), 3rd Ed., World Press, Kolkata, 2005.
4. S.C. Gupta and V.K. Kapoor, *Fundamentals of Applied Statistics*, 4th Ed., Sultan Chand and Sons, 2008.
5. A.M. Kshirsagar, *A Course in Linear Models*, Marcel Dekker, Inc., N.Y., 1983.
6. D.C. Montgomery, *Designs and Analysis of Experiments*, John Wiley and Sons, New York, 2001.
7. D.C. Montgomery, E.A. Peak and G.G. Vinning, *Introduction to Linear Regression Analysis*, 3rd Ed., John Wiley and Sons, 2006.
8. P. Mukhopadhyay, *Theory and Methods of Surveys Sampling*, Prentice Hall of India, 1998.
9. D. Singh and F.S. Chaudhary, *Theory and Analysis of Sample Survey Designs*, New Age International (P) Ltd., 1995.
10. P.V. Sukhatme, B.V. Sukhatme, S. Sukhatme and C. Ashok, *Sampling Theory of Surveys with Applications*, Iowa State University Press, Iowa, USA, 1984.

Core 4.3: Network Analysis and Theory of Sequencing

Flows in networks. Maximal flow. Shortest path and travelling salesman problem. Construction of minimal spanning tree and its applications. Project management through PERT/CPM, Updating of PERT Charts. Project Crashing, Sequencing Problems. Processing n jobs through two/three machines. General n/m job-shop problem.

Books Recommended

1. G. Hadley, *Nonlinear and Dynamic Programming*, Addison-Wesley, 1964.
2. A. Ravindran, D.T. Phillips and James J. Solberg, *Operations Research-Principles and Practice*, John Wiley and Sons, 2005.
3. R.K. Ahuja T. L. Magnanti, B. Orlin, *Network Flows-Theory, Algorithm and Applications*, Prentice Hall, NJ, 1993.
4. J.D. Wist, F.K. Levy, *A Management Guide to PERT/CPM*, 2nd Ed., PHI, 1967 (Reprint 2007).

DSE 1A.1: Matrices

R, R^2, R^3 as vector spaces over R . Standard basis for each of them. Concept of Linear

Independence and examples of different bases.

Subspaces of R^2, R^3 . Translation, Dilation, Rotation, Reflection in a point, line and plane. Matrix form of basic geometric transformations. Interpretation of eigen values and eigenvectors for such transformations and eigen spaces as invariant subspaces. Matrices in diagonal form. Reduction to diagonal form upto matrices of order 3.

Computation of matrix inverses using elementary row operations. Rank of matrix. Solutions of a system of linear equations using matrices. Illustrative examples of above concepts from Geometry, Physics, Chemistry, Combinatorics and Statistics.

Books Recommended

1. A.I. Kostrikin, *Introduction to Algebra*, Springer Verlag, 1984.
2. S. H. Friedberg, A. L. Insel and L.E. Spence, *Linear Algebra*, Prentice Hall of India Pvt. Ltd., New Delhi, 2004.
3. Richard Bronson, *Theory and Problems of Matrix Operations*, Tata McGraw Hill, 1989.

DSE 1A.2: Vector Calculus and Analytical Geometry

Algebra of vectors, Differentiation and partial differentiation of a vector function. Derivative of sum, dot product and cross product of two vectors. Gradient, divergence and curl.

Techniques for sketching parabola, ellipse and hyperbola. Reflection properties of parabola, ellipse and hyperbola. Classification of quadratic equations representing lines, parabola, ellipse and hyperbola. Spheres, Cylindrical surfaces. Illustrations of graphing standard quadric surfaces like cone, ellipsoid.

Books Recommended

1. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
2. H. Anton, I. Bivens and S. Davis, *Calculus*, John Wiley and Sons (Asia) P. Ltd. 2002.
3. P.C. Matthews, *Vector Calculus*, Springer Verlag London Limited, 1998.
4. S.L. Loney, *The Elements of Coordinate Geometry*, McMillan and Company, London.
5. R.J.T. Bill, *Elementary Treatise on Coordinate Geometry of Three Dimensions*, McMillan India Ltd., 1994.

DSE 2A.1: Advanced Statistical Methods

Theory of attributes: Consistency of data, conditions of Consistency, independence and association of attributes, measure of association and contingency

Sampling Distributions: Definition of random sample, parameter and statistic, Sampling distribution of a statistic, standard errors of sample mean, sample proportion and sample moments. Sampling distribution of sample mean and sample variance for normal distribution. Sampling distributions of Chi-square, t and F statistics. distribution of sample correlation coefficient r when $\rho=0$

Tests of significance: Null and alternative hypotheses, level of significance and probabilities of Type I and Type II errors, critical region and power of test. Large sample test, use of CLT for testing single proportion and difference of two proportions, single mean and difference of two means. Standard deviation and difference of Standard deviations. Tests of significance based of Chi-square, t and F distributions.

Order Statistics: Distribution of r -th order statistic, smallest and largest order statistics.

Books Recommended

1. A.M. Goon, M.K. Gupta and B. Dasgupta, *An Outline of Statistical Theory* (Vol. I), 4th Ed., World Press, Kolkata, 2003.
2. S.C. Gupta and V.K. Kapoor, *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand and Sons, 2007.
3. R.V. Hogg, A.T. Craig and J.W. McKean, *Introduction to Mathematical Statistics*, 6th Ed., Pearson Education, 2005.
4. P. Mukhopadhyay, *Mathematical Statistics*, 2nd Ed., Books and Allied (P) Ltd., 2000.
5. V.K. Rohtagi and A.K. Md. E. Saleh, *An Introduction to Probability and Statistics*, 2nd Ed., John Wiley and Sons, 2009.

DSE 2A.2: Statistical Methodology

Bivariate Data: Scatter diagram, Principal of least squares and fitting of polynomial and exponential curves, Correlation and regression: Karl Pearson coefficient of correlation, lines of regression, Spearman's rank correlation coefficient, multiple and partial correlations (for 3 variates only).

Limit theorems: Markov's inequality, Chebyshev's inequality, weak and strong laws of large numbers, central limit theorems (Lindeberg-Levy).

Order Statistics: Distribution of r -th order statistic, smallest and largest order statistics.

Sampling Distribution: Concept of random sample, parameter and statistic, sampling distribution of a statistic, standard errors of sample mean and sample proportion, sampling distribution of sample mean and sample variance for a normal population.

Hypothesis Testing: Simple, composite, null and alternative hypothesis, level of significance, two types of errors. Critical region and power of test, large sample test. Tests of significance based on chi-square, t and F Statistics.

Books Recommended:

1. J.E. Freund, *Mathematical Statistics with Applications*, 7th Ed., Pearson Education, 2009.
2. A.M. Goon, M.K. Gupta and B. Dasgupta, *Fundamentals of Statistics* (Vol. I), 8th Ed., World Press, Kolkata, 2005.
3. A.M. Goon, M.K. Gupta and B. Dasgupta, *Fundamentals of Statistics* (Vol. II), 8th Ed. World Press, Kolkata, 2005.

4. S.C. Gupta and V.K. Kapoor, *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand and Sons, 2007.
5. R.V. Hogg, A.T. Craig and J.W. McKean, *Introduction to Mathematical Statistics*, 6th Ed. Pearson Education, 2005.
6. A.M. Mood, F.A. Graybill and D.C. Boes, *Introduction to the Theory of Statistics*, 3rd Ed., Tata McGraw-Hill Pub. Co. Ltd., 2007.
7. S.M. Ross, *Introduction to Probability Models*, 9th Ed., Academic Press, 2007.

DSE 3A.1: Queueing and Reliability Theory

General concepts of queueing system, Measures of performance, Arrival and Service Processes, Single server and multi server models, channels in parallel with limited and unlimited queues- M/M/1/K, M/M/C. Queues with unlimited service. Finite source queues. Application of simple queueing decision model's, Design and control models.

Basics of reliability. Classes of life distributions. Series, parallel, configurations. Reliability models, Reliability, Mean Time before failure and Hazard rate of Exponential and Weibull distributions. Concepts and definitions of preventive maintenance, corrective maintenance and age replacement.

Books Recommended

1. R.B. Cooper, *Introduction to Queueing Theory*, 2nd Ed., North Holland, 1981.
2. D. Gross, C. M. Harris, *Fundamentals of Queueing Theory*, 3rd Ed., John Wiley and Sons Inc. P. Ltd., 2002.
3. U.N. Bhat, *An Introduction to Queueing Theory: Modelling and Analysis in Applications (Statistics for Industry and Technology)*, Birkhauser Boston, 2008.
4. U.N. Prabhu, *Foundations of Queueing Theory*, International Series in Operations Research & Management Science, Kluwer Academic Publishers, 2nd Ed., 2002.
5. John G. Rau, *Optimization and Probability in Systems Engineering*, V.N. Reinhold Co., 1970.
6. Riccardo Manzini, Alberto Regattieri, Hoang Pham, Emilio Ferrai, *Maintenance for Industrial Systems*, Springer-Verlag, London Limited, 2010.
7. P.K. Kapur, R.B. Garg, S. Kumar, *Contributions to Hardware and Software Reliability*, World Scientific, Singapore, 1999.

DSE 3A.2: Optimization Techniques

Dynamic Programming: Multistage decision processes, Recursive nature of computations, Forward and Backward recursion, Bellman's principle of optimality, Selective dynamic programming applications involving additive and multiplicative separable returns for objective as well as constraint functions, Problem of dimensionality.

Goal Programming: Weighted and pre-emptive goal programming, graphical solution

Decision Analysis: Decision making under risk – Decision tree analysis, Posterior (Baye's) probabilities, Decision under uncertainty- criterion of pessimism, criterion of optimism, Laplace criterion, criterion of realism, criterion of regret.

Books Recommended

1. Hamdy A. Taha, *Operations Research - An Introduction*, Prentice Hall, 8th Ed., 2008.
2. S. Chandra, Jayadeva, Aparna Mehra, *Numerical Optimization with Application*, Narosa Publishing House, 2009.

DSE 1B.1: Complex Analysis

Limits, Limits involving the point at infinity, continuity. Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings. Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability.

Analytic functions, examples of analytic functions, exponential function, Logarithmic function, trigonometric function, derivatives of functions, definite integrals of functions. Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals. Cauchy-Goursat theorem, Cauchy integral formula.

Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and series, Taylor series and its examples.

Laurent series and its examples, absolute and uniform convergence of power series.

Books Recommended

1. James Ward Brown and Ruel V. Churchill, *Complex Variables and Applications*, 8th Ed., McGraw – Hill International Edition, 2009.
2. Joseph Bak and Donald J. Newman, *Complex analysis*, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.

DSE 1B.2: Linear Algebra

Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.

Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations.

Isomorphisms, Isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix.

Books Recommended

1. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra*, 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
2. David C. Lay, *Linear Algebra and its Applications*, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
3. S. Lang, *Introduction to Linear Algebra*, 2nd Ed., Springer, 2005.
4. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.

DSE 2B.1: Econometrics

Nature and Scope of Econometrics.

Statistical Concepts Normal distribution; chi-square, t and F-distributions; estimation of parameters; properties of estimators; testing of hypotheses: defining statistical hypotheses; distributions of test statistics; testing hypotheses related to population parameters; Type I and Type II errors; level of significance, power of a test; tests for comparing parameters from two samples.

Simple Linear Regression Model: Two Variable Case Estimation of model by method of ordinary least squares; properties of estimators; goodness of fit; tests of hypotheses; scaling and

units of measurement; confidence intervals; Gauss-Markov theorem; forecasting.

Multiple Linear Regression Model Estimation of parameters; properties of OLS estimators; goodness of fit - R^2 and adjusted R^2 ; partial regression coefficients; testing hypotheses – individual and joint; functional forms of regression models; qualitative (dummy) independent variables.

Violations of Classical Assumptions: Consequences, Detection and Remedies Multicollinearity; heteroscedasticity; serial correlation.

Specification Analysis Omission of a relevant variable; inclusion of irrelevant variable; tests of specification errors.

Books Recommended

1. Jay L. Devore, *Probability and Statistics for Engineers*, Cengage Learning, 2010.
2. John E. Freund, *Mathematical Statistics*, Prentice Hall, 1992.
3. Richard J. Larsen and Morris L. Marx, *An Introduction to Mathematical Statistics and its Applications*, Prentice Hall, 2011.
4. D.N. Gujarati and D.C. Porter, *Essentials of Econometrics*, 4th Ed., McGraw Hill, International Edition, 2009.
5. Christopher Dougherty, *Introduction to Econometrics*, 3rd Ed., Oxford University Press, 2007.
6. Jan Kmenta, *Elements of Econometrics*, 2nd Ed., Khosla Publishing House, 2008.

DSE 2B.2: Applied Statistics

Economics Statistics: Time Series Analysis-economic time series, different components, Illustrations, additive and multiplicative models, determination of trend, analysis of seasonal fluctuations. Index numbers-criteria for a good index number. Different types of index numbers, Construction of index numbers of prices and qualities. Cost of living index number. Uses and limitations of index numbers.

Statistical Quality Control: Importance of statistical methods in industrial research and practice, determination of tolerance limits, general theory of control charts, process and product control, causes of variation in quality, control limits, summary of out of control criteria, charts for attributes-p-chart, np-chart, c-chart; charts for variables- \bar{X} , R and s-charts, principles of acceptance sampling, problem of lot acceptance, producer's and consumer's risks, single sampling instruction plan and its OC and ASN functions, concepts of AQL, LTPD, AOQL, ATI functions; Dodge and Romig Tables.

Demographic Methods: Sources of demographic data-census, register, ad hoc surveys, hospital records, demographic profiles of Indian census, questionnaire, errors in these data and their adjustment. Measurements of Mortality-CDR, SDR (w.r.t. age and sex), IMR, standardized death rate, complete life table, its main features and uses. Measurements of fertility and reproduction-CBR, General, Age-specific and total fertility rates, GRR, NRR.

Books Recommended

1. A.M. Goon, M.K. Gupta and B. Dasgupta, *An Outline of Statistical Theory* (Vol. I), 4th Ed., World Press, Kolkata, 2003.
2. S.C. Gupta and V.K. Kapoor, *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand and Sons, 2007.
3. P. Mukhopadhyay, *Mathematical Statistics*, 2nd Ed. Books and Allied (P) Ltd., 2000.
4. F.E. Croxton and D.J. Cowden, *Applied General Statistics*, Prentice Hall of India, 1969.

5. M.G. Kendall and A. Stuart, *The Advanced Theory of Statistics* (Vol. III), Macmillan Publishing Co. Inc., 1977.
6. D.C. Montgomery, *Introduction to Statistical Quality Control*, John Wiley and Sons, New York, 1996.

DSE 3B.1: Integer Programming and Theory of Games

Integer Linear Programming. Modeling using pure and mixed integer programming, Branch and Bound Technique, Gomory's Cutting Plane Algorithm.

Game theory: formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games.

Books Recommended

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, *Linear Programming and Network Flows*, 2nd Ed., John Wiley and Sons, India, 2004.
2. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, 9th Ed., Tata McGraw Hill, Singapore, 2009.
3. Hamdy A. Taha, *Operations Research, An Introduction*, 8th Ed., Prentice-Hall India, 2006.

DSE 3B.2: Forecasting

Introduction to forecasting, Types of forecast, Basic forecasting tools. Time Series and its Components. Linear and Nonlinear Trend, seasonal Variations and Irregular Variations and their Measurements. Moving Averages. Single and Double exponential smoothing.

Books Recommended:

1. John E. Hanke, Dean Wichern and Arthur G. Reitch, *Business Forecasting*, 7th Ed., Pearson, 2008.
2. J. Holton, Wilson and Barry Keating, *Business Forecasting Wforecast*, 6th Ed., Tata McGraw Hill, 2009.
3. S.C. Gupta and V.K. Kapoor, *Fundamentals of Applied Statistics*, Sultan Chand and Sons, 2009.
4. G. Hadley, T.M. Whitin, *Analysis of Inventory Systems*, D.B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc., 1979.

SEC 1.1: Logic and Sets

Introduction, propositions, truth table, negation, conjunction and disjunction. Implications, biconditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, Quantifiers, Binding variables and Negations.

Sets, subsets, Set operations, the laws of set theory and Venn diagrams. Examples of finite and infinite sets. Finite sets and counting principle. Empty set, properties of empty set. Standard set operations. Classes of sets. Power set of a set.

Difference and Symmetric difference of two sets. Set identities, Generalized union and intersections. Relation: Product set, Composition of relations, Types of relations, Partitions, Equivalence Relations with example of congruence modulo relation.

Book Recommended

1. R.P. Grimaldi, *Discrete Mathematics and Combinatorial Mathematics*, Pearson Education, 1998.
2. P.R. Halmos, *Naive Set Theory*, Springer, 1974.
3. E. Kamke, *Theory of Sets*, Dover Publishers, 1950.

SEC 1.2: Integral Calculus

Integration by Partial fractions, integration of rational and irrational functions. Properties of definite integrals. Reduction formulae for integrals of rational, trigonometric, exponential and logarithmic functions and of their combinations.

Evaluation of areas and lengths of curves in the plane, valuation of volumes and surfaces of solids of revolution. Double and Triple integrals.

Books Recommended

1. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
2. H. Anton, I. Bivens and S. Davis, *Calculus*, John Wiley and Sons (Asia) P. Ltd. 2002.

SEC 2.1: Portfolio Optimization

Financial markets. Investment objectives. Measures of return and risk. Types of risks. Portfolio of assets. Expected risk and return of portfolio. Diversification. Mean-variance portfolio optimization- the Markowitz model and the two-fund theorem, risk-free assets and one fund theorem, efficient frontier. Portfolio performance evaluation measures.

Books Recommended

1. F.K. Reilly, Keith C. Brown, *Investment Analysis and Portfolio Management*, 10th Ed., South-Western Publishers, 2011.
2. H.M. Markowitz, *Mean-Variance Analysis in Portfolio Choice and Capital Markets*, Blackwell, New York, 1987.
3. D.G. Luenberger, *Investment Science*, 2nd Ed., Oxford University Press, 2013.

SEC 2.2: Bio-Mathematics

Mathematical Biology and the modeling process: an overview. Continuous models: Malthus model, logistic growth, Allee effect, Gompertz growth, Michaelis-Menten Kinetics, Holling type growth, Bacterial growth in a Chemostat, Harvesting a single natural population, Prey predator systems and Lotka-Volterra equations, Populations in competitions, Epidemic Models (SI, SIR, SIRS, SIC), Activator-Inhibitor system, Insect Outbreak Model: Spruce Budworm, Numerical solution of the models and its graphical representation. Qualitative analysis of continuous models: Steady state solutions, stability and linearization, multiple species communities and Routh-Hurwitz Criteria.

Spatial Models: One species model with diffusion. Discrete Models: Overview of difference equations, steady state solution and linear stability analysis, Introduction to Discrete Models, Linear Models, Growth models, Decay models.
Case Studies: Optimal Exploitation models, Models in Genetics.

Books Recommended

1. L.E. Keshet, *Mathematical Models in Biology*, SIAM, 1988.
2. J.D. Murray, *Mathematical Biology*, Springer, 1993.
3. Y.C. Fung, *Biomechanics*, Springer-Verlag, 1990.
4. F. Brauer, P.V.D. Driessche and J. Wu, *Mathematical Epidemiology*, Springer, 2008.
- 5 M. Kot, *Elements of Mathematical Ecology*, Cambridge University Press, 2001.

SEC 3.1: Number Theory

Division algorithm, Lame's theorem, linear Diophantine equation, fundamental theorem of arithmetic, prime counting function, statement of prime number theorem. Goldbach conjecture, binary and decimal representation of integers, linear congruences, complete set of residues. Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Möbius inversion formula, the greatest integer function, Euler's phi-function.

Books Recommended

1. David M. Burton, *Elementary Number Theory*, 6th Ed., Tata McGraw-Hill Edition, Indian reprint, 2007.
2. Richard E. Klima, Neil Sigmon, Ernest Stitzinger, *Applications of Abstract Algebra with Maple*, CRC Press, Boca Raton, 2000.
3. Neville Robinns, *Beginning Number Theory*, 2nd Ed., Narosa Publishing House Pvt. Limited, Delhi, 2007.

SEC 3.2: Theory of Equations

General properties of polynomials, Graphical representation of a polynomials, maximum and minimum values of a polynomial, General properties of equations, Descarte's rule of signs positive and negative rule, Relation between the roots and the coefficients of equations. Symmetric functions, Applications of symmetric function of the roots, Transformation of equations. Solutions of reciprocal and binomial equations. Algebraic solutions of the cubic and biquadratic equations.
Properties of the derived functions.

Books Recommended

1. W.S. Burnside and A.W. Panton, *The Theory of Equations*, Dublin University Press, 1954.
2. C. C. MacDuffee, *Theory of Equations*, John Wiley & Sons Inc., 1954.

SEC 4.1: Mathematical Finance

Basic principles: Comparison, arbitrage and risk aversion, Interest (simple and compound, discrete and continuous), time value of money, inflation, net present value, internal rate of return (calculation by bisection and Newton-Raphson methods), comparison of NPV and IRR. Bonds, bond prices and yields. floating-rate bonds, immunization.

Asset return, short selling, portfolio return, (brief introduction to expectation, variance, covariance and correlation), random returns, portfolio mean return and variance, diversification, portfolio diagram, feasible set, Markowitz model (review of Lagrange multipliers for 1 and 2 constraints).

Books Recommended:

1. David G. Luenberger, *Investment Science*, Oxford University Press, Delhi, 1998.
2. John C. Hull, Options, *Futures and Other Derivatives*, 6th Ed., Prentice-Hall India, Indian reprint, 2006.
3. Sheldon Ross, *An Elementary Introduction to Mathematical Finance*, 2nd Ed., Cambridge University Press, USA, 2003.

SEC 4.2: Understanding Probability and Statistics through Practicals

Practical/ Lab work to be performed on a computer using Excel.

Practicals should broadly cover the following areas:

- (i) Fitting of Binomial, Poisson, Negative Binomial, Normal Distributions.
- (ii) Applications of Chi-square, t and F Distributions.
- (iii) Calculation of correlation coefficient, Rank Correlation, etc.
- (iv) Fitting of polynomials and regression curves.
- (v) Methods of estimation (MLE and method of Moments)
- (vi) Selecting a simple random sample using random number tables.

Books Recommended:

1. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, *Introduction to Mathematical Statistics*, Pearson Education, Asia, 2007.
2. Irwin Miller and Marylees Miller, John E. Freund, *Mathematical Statistics with Applications*, 7th Ed., Pearson Education, Asia, 2006.
3. Sheldon Ross, *Introduction to Probability Models*, 9th Ed., Academic Press, Indian Reprint, 2007.