Proposed Syllabus and Scheme of Examination

for

B.Sc. Mathematical Sciences

submitted to

University Grants Commission
New Delhi

under the

Choice Based Credit System

May 2015
### Proposed Scheme for Choice Based Credit System in B.Sc. Mathematical Sciences

<table>
<thead>
<tr>
<th>Semester</th>
<th>Core Course (12)</th>
<th>Ability Enhancement Compulsory Course (AECC) (2)</th>
<th>Skill Enhancement Course (SEC) (2)</th>
<th>Discipline Specific Elective (DSE) (6)</th>
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<tr>
<td>1</td>
<td>Differential Calculus</td>
<td>AECC1</td>
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<td></td>
<td>Descriptive Statistics and Probability Theory</td>
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<td>Linear Programming</td>
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<td>2</td>
<td>Differential Equations</td>
<td>AECC2</td>
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<td>Statistical Methods</td>
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<td>Mathematical Programming</td>
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<td>3</td>
<td>Real Analysis</td>
<td>SEC 1</td>
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<td>Statistical Inference</td>
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<td>Inventory Systems and Marketing Management</td>
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<td>4</td>
<td>Algebra</td>
<td>SEC 2</td>
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<td>Sample Surveys and Design of Experiments</td>
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<td>Network Analysis and Theory of Sequencing</td>
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<td>SEC 3</td>
<td>DSE 1A</td>
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<td>DSE 2A</td>
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<td>DSE 3A</td>
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<td>SEC 4</td>
<td>DSE 1B</td>
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<td>DSE 3B</td>
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Discipline Specific Electives (DSE)

DSE 1A (choose one)
1. Matrices
2. Vector Calculus and Analytical Geometry

DSE 2A (choose one)
1. Advanced Statistical Methods
2. Statistical Methodology

DSE 3A (choose one)
1. Queueing and Reliability Theory
2. Optimization Techniques

DSE 1B (choose one)
1. Complex Analysis
2. Linear Algebra

DSE 2B (choose one)
1. Econometrics
2. Applied Statistics

DSE 3B (choose one)
1. Integer Programming and Theory of Games
2. Forecasting

Skill Enhancement Course (SEC)

SEC 1 (choose one)
1. Logic and Sets
2. Integral Calculus

SEC 2 (choose one)
1. Portfolio Optimization
2. Bio-Mathematics

SEC 3 (choose one)
1. Number Theory
2. Theory of Equations
SEC 4 (choose one)
  1. Mathematical Finance
  2. Understanding Probability and Statistics through Practicals
Details of Courses under B.Sc. Mathematical Sciences

<table>
<thead>
<tr>
<th>Course</th>
<th>*Credits</th>
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<td>Theory + Practical</td>
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**I. Core Course**
(12 Papers)
04 Courses from each of the 03 disciplines of choice

<table>
<thead>
<tr>
<th>Core Course Practical / Tutorial*</th>
<th>12×2 = 24</th>
<th>12×1 = 12</th>
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<tbody>
<tr>
<td>(12 Practical/ Tutorials*)</td>
<td></td>
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<tr>
<td>04 Courses from each of the 03 Disciplines of choice</td>
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</table>

**II. Elective Course**
(6 Papers)
Two papers from each discipline of choice including paper of interdisciplinary nature.

<table>
<thead>
<tr>
<th>Elective Course Practical / Tutorials*</th>
<th>6×2 = 12</th>
<th>6×1 = 6</th>
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<tr>
<td>(6 Practical / Tutorials*)</td>
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</tr>
<tr>
<td>Two Papers from each discipline of choice including paper of interdisciplinary nature</td>
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• Optional Dissertation or project work in place of one Discipline elective paper (6 credits) in 6th Semester

**III. Ability Enhancement Courses**

1. Ability Enhancement Compulsory 2×2 = 4 2×2 = 4
(2 Papers of 2 credits each)

Environmental Science
English/MIL Communication
2. Skill Enhancement Course  
(Skill Based) (4 Papers of 2 credits each)

\[
\begin{array}{cc}
4 \times 2 & = 8 \\
4 \times 2 & = 8 \\
\end{array}
\]

Total credit = 120

Institute should evolve a system/policy about ECA/ General Interest/ Hobby/ Sports/ NCC/ NSS/ related courses on its own.

*wherever there is practical there will be no tutorials and vice-versa
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.


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(1+x), (1+x)^m, Maxima and Minima, Indeterminate forms.

Books Recommended


Core 1.2: 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). Theorem on probability, conditional probability, independent events. Baye’s theorem and its applications.

Books Recommended


Core 1.3: Linear Programming


Books Recommended


Core 2.1: Differential Equations


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

Books Recommended


Core 2.2: 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. 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 Gama distributions.

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

Books Recommended


Core 2.3: Mathematical Programming

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


Books Recommended


**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. $M_\text{p}$-test, $M$-test, Statements of the results about uniform convergence and integrability and differentiability of functions, Power series and radius of convergence.

**Books Recommended**


Core 3.2: Statistical Inference


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

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


Core 4.1: Algebra

Definition and examples of groups, examples of abelian and non-abelian groups, the group $\mathbb{Z}_n$ 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 $\text{GL}_n(n,\mathbb{R})$, groups of symmetries of (i) an isosceles triangle, (ii) an equilateral triangle, (iii) a rectangle, and (iv) a square, the permutation group $\text{Sym}(n)$, 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, $\mathbb{Z}_n$ 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: $\mathbb{Z}_p$, $\mathbb{Q}$, $\mathbb{R}$, and $\mathbb{C}$. Field of rational functions.

Books Recommended


Core 4.2: Sample Surveys and Design of Experiments


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 trails, completely randomized, Randomized block and Latin square designs. Missing plot technique, $2^2$ and $2^3$ Factorial experiments: construction and analysis.

Regression Analysis: Two variable linear model – estimation, testing and problems of predication. Predication of the estimated regression equation, interval estimation, variance estimation.

Books Recommended


Core 4.3: Network Analysis and Theory of Sequencing


Books Recommended


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.


Books Recommended


DSE 1A.2: Vector Calculus and Analytical Geometry


Books Recommended

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


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.


Books Recommended:

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.


Books Recommended

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


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.


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


**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**


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; 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 - R2 and adjusted R2 ; 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


DSE 2B.2: Applied Statistics


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


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


DSE 3B.2: Forecasting


Books Recommended:


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.


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


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

SEC 2.1: Portfolio Optimization


Books Recommended

SEC 2.2: Bio-Mathematics


Case Studies: Optimal Exploitation models, Models in Genetics.

Books Recommended

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


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.


Properties of the derived functions.

Books Recommended

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:


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: