Course Curriculum (Syllabus for CBCS)

For the Academic Years

2014, 2015 & 2016 (For I & II Semesters)

2015, 2016 & 2017 (For III & IV Semesters)
CHOICE BASED CREDIT SYSTEM (CBCS)

CORE COURSES- (SEMESTER –I)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
</tr>
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<tbody>
<tr>
<td>MM- CR -101</td>
<td>Advanced Abstract Algebra-I</td>
<td>4</td>
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<tr>
<td>MM –CR- 102</td>
<td>Real Analysis-I</td>
<td>4</td>
</tr>
<tr>
<td>MM- CR- 103</td>
<td>Topology</td>
<td>4</td>
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OPTIONAL COURSES (SEMESTER –I)

<table>
<thead>
<tr>
<th>Course Code</th>
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<th>Credits</th>
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<tbody>
<tr>
<td>MM- EA -104</td>
<td>Theory of Numbers-I</td>
<td>4</td>
</tr>
<tr>
<td>MM- EA -105</td>
<td>Matrix Algebra</td>
<td>4</td>
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<tr>
<td>MM –EA- 106</td>
<td>Computational Mathematics</td>
<td>4</td>
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<tr>
<td>MM- EA -107</td>
<td>Advanced Calculus</td>
<td>2</td>
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<tr>
<td>MM -EA -108</td>
<td>Probability Theory</td>
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</tr>
<tr>
<td>MM- EO -109</td>
<td>Other Allied + Open</td>
<td>4</td>
</tr>
</tbody>
</table>

General Instructions for the Candidates

1. The two year (4 semester) PG programmes is of 96 credit weightage i.e., 24 credits/semester(24x4=96).
2. A candidate has compulsory to opt for 12 credits from the core component in each semester.
3. A candidate has a choice to opt for any 12 credits(3 papers) out of minimum of 16 credits(4 papers) offered as Electives(Allied), except for a particular semester as mentioned by the Department where a candidate is required to gain a minimum of 4 credits( 1 paper) from Elective(Open) offered by any other Department.
4. A candidate has compulsorily to obtain a minimum of 4 credits (1 paper) from Elective (Open) from outside the parent Department in any of the semesters.
5. A candidate can earn more than the minimum required credits (i.e., more than 96 credits for four semester programme) which shall be counted towards the final result of the candidate.
### CORE COURSES- (SEMESTER -II)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
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<tbody>
<tr>
<td>MM-CR-201</td>
<td>Discrete Mathematics</td>
<td>4</td>
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<tr>
<td>MM-CR-202</td>
<td>Real Analysis-II</td>
<td>4</td>
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<tr>
<td>MM-CR-203</td>
<td>Complex Analysis-I</td>
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### OPTIONAL COURSES (SEMESTER -II)

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<tr>
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<tbody>
<tr>
<td>MM-EA-204</td>
<td>Theory of Numbers-II</td>
<td>4</td>
</tr>
<tr>
<td>MM-EA-205</td>
<td>Operations Research</td>
<td>4</td>
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<tr>
<td>MM-EA-206</td>
<td>Fourier Analysis</td>
<td>4</td>
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<tr>
<td>MM-EA-207</td>
<td>Linear Algebra</td>
<td>2</td>
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<tr>
<td>MM-EA-208</td>
<td>Numerical Analysis</td>
<td>2</td>
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<tr>
<td>MM-EA-209</td>
<td>Mathematical Modelling</td>
<td>2</td>
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<tr>
<td>MM-EA-210</td>
<td>Integral Equations</td>
<td>2</td>
</tr>
<tr>
<td>MM-EO-211</td>
<td>Other Allied + Open</td>
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</table>

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**CORE COURSES (SEMESTER –IV)**

<table>
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<tr>
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<tbody>
<tr>
<td>MM-CR-401</td>
<td>Partial Differential Equations</td>
<td>4</td>
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<tr>
<td>MM-CR-402</td>
<td>Differential Geometry</td>
<td>4</td>
</tr>
<tr>
<td>MM-CR-403</td>
<td>Advanced Abstract Algebra-II</td>
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**OPTIONAL COURSES (SEMESTER –IV)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
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<tbody>
<tr>
<td>MM-EA-404</td>
<td>Analytic Theory of Polynomials</td>
<td>4</td>
</tr>
<tr>
<td>MM-EA-405</td>
<td>Mathematical Statistics</td>
<td>4</td>
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<tr>
<td>MM-EA-406</td>
<td>Functional Analysis-II</td>
<td>4</td>
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<tr>
<td>MM-EA-407</td>
<td>Non-Linear Analysis</td>
<td>4</td>
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<tr>
<td>MM-EA-408</td>
<td>Advanced Topics in Topology and Modern Analysis</td>
<td>4</td>
</tr>
<tr>
<td>MM-EA-409</td>
<td>Project</td>
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<td>MM-EO-410</td>
<td>Other Allied + Open</td>
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</table>

**General Instructions for the Candidates**

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5. A candidate can earn more than the minimum required credits (i.e., more than 96 credits for four semester programme) which shall be counted towards the final result of the candidate.
6. Project will consists of two components:
   a) Writing of Dissertation on a certain chosen topic.
   b) Viva-Voce.
   (Each component will carry 50 marks).
7. The Academic Tour shall be conducted by the Department every year for outgoing students (4th semester).
SEMESTER-I

ADVANCED ABSTRACT ALGEBRA-I

Course No: MM-CR-101  Max. Marks: 100
Duration of Examination: 2:30 Hrs.  External Exam: 80
No. of Credits: 04  Internal Assessment: 20

CREDIT-I

Definitions and examples of Semi-groups and Monoids. Criteria for the semi-groups to be a group; Cyclic groups; Structure theorem for cyclic groups. Endomorphism, Automorphism, Inner Automorphism and Outer Automorphism, Center of a group, Cauchy’s and Sylow’s theorem for abelian groups. Permutation groups, Symmetric groups, Alternating groups, Simple groups, Simplicity of the Alternating group \( A_n \) for \( n \geq 5 \).

CREDIT-II

Normalizer, conjugate classes, Class equation of a finite group and its applications, Cauchy’s theorem and Sylow’s theorems for finite groups. Double cosets, Second and third parts of Sylow’s theorem. Direct product of groups, Finite abelian groups, normal and subnormal series, Composition series. Jordan Holder theorem for finite groups. Zassenhaus Lemma, Schreir’s Refinement theorem, Solvable groups.

CREDIT-III

Brief review of Rings, Integral domain, Ideals. The field of quotients of an Integral domain. Embedding of an Integral domain. Euclidean rings with examples such as \( \mathbb{Z}[\sqrt{-1}] \), \( \mathbb{Z}[\sqrt{2}] \), Principal ideal rings (PIR) Unique factorization domains (UFD) and Euclidean domains, Greatest common divisor, Lowest common multiple in rings, Relationships between Euclidean rings, P.I.R.’s and U.F.D.

CREDIT-IV

Polynomial rings: The Division algorithm for polynomials, Irreducible polynomials, Polynomials and the rational field, Primitive polynomials, Contract of a polynomials, Gauss Lemma, Integer monic polynomial, Eisenstein’s irreducibility criterion, cyclotomic polynomials; Polynomial rings and Commutative rings.
Recommended Books

1. I.N.Herstein : Topics in Algebra.
REAL ANALYSIS - I

Course No: **MM-CR-102**
Duration of Examination: 2:30 Hrs.
No. of Credits: **04**

Max. Marks: 100
External Exam: 80
Internal Assessment: 20

CREDIT-I
Integration: Definition and existence of Riemann – Stieltje’s integral, behavior of upper and lower sums under refinement, Necessary and sufficient conditions for RS-integrability of continuous and monotonic functions, Reduction of an RS-integral to a Riemann integral, Basic properties of RS-integrals, Differentiability of an indefinite integral of a continuous functions, The fundamental theorem of calculus for Riemann integrals.

CREDIT-II

CREDIT-III

CREDIT-IV
Sequence and series of functions: Point wise and uniform convergence, Cauchy criterion for uniform convergence, Mₙ .test, Weiestrass M-test, Abel’s and Dirichlet’s test for uniform convergence, uniform convergences and continuity, R- integration and differentiation, Weiestrass Approximation theorem. Example of continuous nowhere differentiable function.

Recommended Books:
1. R. Goldberg : Methods of Real Analysis.
6. L.Royden : Real Analysis.
TOPOLOGY

Course No: **MM-CR-103**  Max. Marks: 100
Duration of Examination: 2:30 Hrs.  External Exam: 80
No. of Credits: **04**  Internal Assessment: 20

**CREDIT-I**

Review of countable and uncountable sets, Schroeder-Bernstein theorem, Axiom of Choice and its various equivalent forms, Definition and examples of metric spaces, Open and Closed sets, completeness in metric spaces, Baire’s Category theorem, and applications to the (1) Non-existence of a function which is continuous precisely at irrationals (ii) Impossibility of approximating the characteristic of rationals on [0, 1] by a sequence of continuous functions.

**CREDIT-II**

Completion of a metric space, Cantor’s intersection theorem, with examples to demonstrate that each of the conditions in the theorem is essential, Uniformly continuous mappings with examples and counter examples, Extending Uniformity continuous maps, Banach’s contraction principle with applications to the inverse function theorem in R.

**CREDIT-III**

Topological spaces; Definition and examples, elementary properties, Kuratowski’s axioms, continuous mappings and their characterizations, pasting Lemma, convergence of nets and continuity in terms of nets, Bases and sub bases for a topology, Lower limit topology, concepts of first countability, second countability, separability and their relationships, counter examples and behavior under subspaces, product topology and weak topology, compactness and its various characterizations.
CREDIT-IV

Heine-Borel theorem, Tychonoff’s theorem, compactness, sequential compactness and total boundedness in metric spaces. Lebesgue’s covering lemma, continuous maps on a compact space. Separation axioms $T_i$ ($i=1,2,3,31/2,4$) and their permanence properties, connectedness, local connectedness, their relationship and basic properties, Connected sets in $\mathbb{R}$. Urysohn’s lemma. Urysohn’s metrization theorem. Tietze’s extension theorem, one point compactification.

Recommended Books:

1. G.F. Simmons : Introduction to topology and Modern Analysis.
# THEORY OF NUMBERS-I

<table>
<thead>
<tr>
<th>Course No. <strong>MM-EA-104</strong></th>
<th>Max. Marks: 100</th>
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<td>External Exam: 80</td>
</tr>
<tr>
<td>No. of Credits: <strong>04</strong></td>
<td>Internal Assessment: 20</td>
</tr>
</tbody>
</table>

## CREDIT-I


## CREDIT-II

Sequence of primes, Euclid’s Second theorem, Infinitude of primes of the form \( 4n+3 \) and of the form \( 6n+5 \). No polynomial \( f(x) \) with integral coefficients can represent primes for all integral values of \( x \) or for all sufficiently large \( x \). Fermat Numbers and their properties. Fermat Numbers are relatively prime. There are arbitrary large gaps in the sequence of primes. Congruences, Complete Residue System (CRS), Reduced Residue System (RRS) and their properties. Fermat and Euler’s theorems with applications.

## CREDIT-III

Euler’s \( \phi \)-function, \( \phi (mn) = \phi (m) \phi (n) \) where \( (m, n) = 1 \), \( \sum_{d|m} \phi(d) = n \) and \( \phi(m) = m \prod_{p|m} \left(1 - \frac{1}{p}\right) \) for \( m>1 \). Wilson’s theorem and its application to the solution the congruence of \( x^2 \equiv -1 \pmod{p} \), Solutions of linear Congruence’s. The necessary and sufficient condition for the solution of \( a_1x_1 + a_2x_2 +...+a_nx_n \equiv c \pmod{m} \). Chinese Remainder Theorm. Congruences of higher degree \( F(x) \equiv 0 \pmod{m} \), where \( F(x) \) is a Polynomials. Congruence’s with prime power, Congruences with prime modulus and related results. Lagrange’s theorem, viz , the polynomial congruence \( F(x) \equiv 0 \pmod{p} \) of degree \( n \) has at most \( n \) roots.
Factor theorem and its generalization. Polynomial congruences $F(x_1,x_2,...,x_n) \equiv 0 \pmod{p}$ in several variables. Equivalence of polynomials. Theorem on the number of solutions of congruences: Chevalley’s theorem, Warning’s theorem. Quadratic forms over a field of characteristic $\neq 2$ Equivalence of Quadratic forms. Witt’s theorem. Representation of Field Elements. Hermite’s theorem on the minima of a positive definite quadratic form and its application to the sum of two, three and four squares.

**Recommended Books:**


**Suggested Readings:**

2. An introduction to the theory of Numbers by G.H Hardy and Wright.
4. An elementary Number theory of E. Landau.
MATRIX ALGEBRA

Course No: **MM-EA-105**  Max. Marks: 100
Duration of Examination: 2:30 Hrs.  External Exam: 80
No. of Credits: **04**  Internal Assessments: 20

**CREDIT-I**
Eigen values and eigen vectors of a matrix and their determination. The eigen values of a square matrix A are the roots of its characteristic equation and conversely. Similarity of matrices. Two similar matrices have the same eigen values. Algebraic and geometric multiplicity of a characteristic root. Necessary and sufficient condition for a square matrix of order n to be similar to a diagonal matrix. Orthogonal reduction of real matrices.

**CREDIT-II**
Orthogonality of the eigen vectors of a hermetion matrix. The necessary and sufficient condition for a square matrix of order n to be a similar diagonal matrix is that it has a set n linearly independent eigen vectors. If A is a real symmetric matrix then there exists an orthogonal matrix P such that \( P^{-1}AP = \begin{pmatrix} \lambda_1 & 0 & \cdots & 0 \\ 0 & \lambda_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \lambda_n \end{pmatrix} \). Semi – diagonal or triangular form. Schur’s theorem. Normal matrices, Necessary and sufficient condition for a square matrix to be unitarily similar to a diagonal matrix.

**CREDIT-III**
**Quadratic forms:** The Kroneckers and Lagranges reduction. Reduction by orthogonal transformation of real quadratic forms. Necessary and sufficient condition for a quadratic form to be positive definite. Rank, Index and signature of a quadratic form. If A=[a_{ij}] is a positive definite matrix of order n, then

\[ |A| \leq a_{11} a_{22} \cdots a_{nn}. \]

**CREDIT-IV**
Gram matrices. The Gram matrix BB\(^T\) is always positive definite or positive semi-definite. Hadmard’s inequality. If B=[b_{ij}] is an arbitrary non- singular real square matrix of order n, then

\[ |B| \leq \prod_{i=1}^{n} \left[ \sum_{k=1}^{n} b_{ik} \right] \]

Functions of symmetric matrices: Positive definite square root of a positive definite matrix. The infinite n-fold integral.
\[ I_n = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \cdots \int_{-\infty}^{\infty} e^{-x'Ax} \, dx, \]

where \( dx = dx_1 dx_2 \cdots dx_n \). If \( A \) is a positive definite matrix, then \( I_n = \frac{\pi^{n/2}}{|A|^{1/2}} \).

If \( A \) and \( B \) are positive definite matrices, then
\[
|\lambda A + (1 - \lambda)B| \geq |A|^\lambda |B|^{1-\lambda} \quad \text{for} \quad 0 \leq \lambda \leq 1
\]

**REFERENCES**

3. A Text Book of Matrices by Shanti Narayan, S. Chand and company Ltd.
COMPUTATIONAL MATHEMATICS

Course No. **MM-EA-106**  Max. Marks: 100
Duration of Examination: 2:30 Hrs.  External Exam: 80
No. of Credits: **04**  Internal Assessment: 20

**CREDIT-I**


**Programming in c Language** – Character set, Variables and Identifiers, Built-in Data Types, Variable Definition, Arithmetic Operators and Expressions, Constants and Literals, Simple Assignment Statement, Basic Input/Output statements, Simple C Programs.


**CREDIT-II**

**Arrays** – One Dimensional Arrays: Array Manipulation; Searching, Insertion, Deletion of an element from an Array, Finding the largest/smallest element in an array, Two Dimensional Arrays: Addition/Multiplication of two matrices, Transpose of a square Matrix, Null Terminated Strings as Array of Characters, Representation of Sparse Matrices.

**Pointers** - Address operators, Pointer type declaration, Pointer assignment, Pointer Initialization, Pointer arithmetic, Function and pointers, Arrays and pointers, Pointer Arrays.
CREDIT-III

Introduction to MATLAB, Basic features, Array and Array Operations: simple Array, Array construction and orientation, Array mathematics, Standard Arrays, manipulation and sorting, Multi Dimensional Arrays: Array construction, Array construction, Array mathematics and manipulation, Relational and Logical operations, Control flow, Functions: M-file function construction rules, I/O arguments, Function workspaces, Functions and the MATLAB search path.

CREDIT-IV

Matrix Algebra: sets of linear equations, matrix functions, special matrices, Data analysis and Statistical functions, Polynomials: roots, multiplications, addition, division, Derivatives and Integrals, evaluation, Fourier analysis: Discrete Fourier transform, Fourier series, Integration and Differentiation, Differential Equations: IVP Format, ODE suit solvers, basic use.

Books Recommended:

1. E.Balagurusamy, Programming in ANSI c.
2. The C Programming Language, Brian W. Kernighan, Dennis M. Ritchie.
4. Mastering MATLAB, Duane Hanselman, Bruce Little field.
5. MATLAB, A Practical approach, Stormy Attaway.
ADVANCED CALCULUS

Course No: **MM-EA-107**  
Max. Marks: 50  
Duration of Examination: 1:15 Hrs.  
External Exam: 40  
No. of Credits: **02**  
Internal Assessment: 10

CREDIT-I

Functions of several variables in $\mathbb{R}^n$, the directional derivative, directional derivative and continuity, total derivative, Matrix of a linear function. Jacobian matrix, chain rule, mean value theorem for differentiable functions.

CREDIT-II

Sufficient conditions for differentiability and for the equality of mixed partials, Taylor’s theorem for functions from $\mathbb{R}^n$ and $\mathbb{R}$. Inverse and Implicit function theorem in $\mathbb{R}^n$. Extremum problems for functions on $\mathbb{R}^n$. Lagrange’s multiplier’s, Multiple Riemann Integral and change of variable formula for multiple Riemann integrals.

Recommended Books:

1. Rudin, W. Principles of Mathematical Analysis.
2. T.M.Apostol: Mathematical Analysis.
PROBABILITY THEORY

Course No: **MM-EA-108**  
Max. Marks: 50  
Duration of Examination: 1:15 Hrs.  
External Exam: 40  
No. of Credits: **02**  
Internal Assessment: 10

**CREDIT-I**

The probability set functions, its properties, probability density function, the distribution function and its properties. Mathematical Expectations, some special mathematical expectations, Inequalities of Makov, Chebyshev and Jensen.

**CREDIT-II**

Conditional probability, independent events, Baye’s theorem, Distribution of two and more random variables, Marginal and conditional distributions, conditional means and variances, Correlation coefficient, stochastic independence and its various criteria.

**Recommended Books:**

<table>
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<tr>
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<th>Max. Marks: 100</th>
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<tr>
<td>No. of Credits: <strong>04</strong></td>
<td>Internal Assessment: 20</td>
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</table>
SEMMESTER-II

DISCRETE MATHEMATICS

Course No: **MM-CR-201**  
Max. Marks: 100
Duration of Examination: 2:30 Hrs.  
External Exam: 80
No. of Credits: **04**  
Internal Assessment: 20

CREDIT-I

**Graphs, traversibility and degrees**

Introduction of graphs, paths and cycles, operations on graphs, bipartite graphs and Konigs theorem, Euler graphs and Euler’s theorem, Konigsberg bridge problem, Hamiltonian graphs and Dirac’s theorem, degree sequences, Wang-Kleitman theorem, Havel-Hakimi theorem, Hakimi’s theorem, Erdos-Gallai theorem, degree sets

CREDIT-II

**Trees and Signed graphs**

Trees and their properties, centres in trees, binary and spanning trees, degrees in trees, Cayley’s theorem, fundamental cycles, generation of trees, Helly property, signed graphs, balanced signed graphs and characterizations

CREDIT-III

**Connectivity and Planarity**

Cut-sets and their properties, Vertex connectivity, edge connectivity, Whitney’s theorem, Menger’s theorem (vertex and edge form), properties of a bond, block graphs, Planar graphs, Kuratowski’s two graphs, Embedding on a sphere, Euler’s formula, Kuratowski’s theorem, geometric dual, Whitney’s theorem on duality, regular polyhedras,

CREDIT-IV

**Matrices and Digraphs**

Incidence matrix $A(G)$, modified incidence matrix $A_f$, cycle matrix $B(G)$, fundamental cycle matrix $B_f$, cut-set matrix $C(G)$, fundamental cut set matrix $C_f$, relation between $A_f$, $B_f$ and $C_f$, path matrix, adjacency matrix, matrix tree theorem, Types of digraphs, types of connectedness, Euler digraphs,
Hamiltonian digraphs, arborescence, matrices in digraphs, Camions theorem, tournaments, characterization of score sequences, Landau’s theorem, oriented graphs and Avery’s theorem.

References

1. R. Balakrishnan, K. Ranganathan, A Text Book of Graph Theory, Springer-Verlag, New York
2. B. Bollobas, Extremal Graph Theory, Academic Press,
3. F. Harary, Graph Theory, Addison-Wesley
4. Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice Hall
5. S. Pirzada, An Introduction to Graph Theory, Universities Press, OrientBlackswan, 2012
6. W. T. Tutte, Graph Theory, Cambridge University Press
7. D. B. West, Introduction to Graph Theory, Prentice Hall
REAL ANALYSIS-II

Course No: MM-CR-202                       Max. Marks:       100
Duration of Examination: 2:30 Hrs.            External Exam:    80
No. of Credits: 04                           Internal Assessment: 20

CREDIT-I

Measure theory: Definition of outer measure and its basic properties, Outer measure of an interval as its length. Countable additivity of the outer measure, Borel measurable sets and Lebesgue measurability of Borel sets, Cantor set, existence of non-measurable sets and of measurable sets which are not Borel, Outer measure of monotonic sequences of sets.

CREDIT-II

Measurable functions and their characterization. Algebra of measurable functions, Stienhauss theorem on sets of positive measure, Ostrovisk’s theorem on measurable solution of \( f (x+y)= f(x) + f(y) , x,y \in \mathbb{R} \). Convergence a.e., convergence in measure and almost uniform convergence, their relationship on sets of finite measure, Egoroff’s theorem.

CREDIT-III


CREDIT-IV

Absolute continuity and bounded variation, their relationships and counter examples. Indefinite integral of a L-integrable functions and its absolute continuity. Necessary and sufficient condition for bounded variation. Vitali’s covering lemma and a.e. differentiability of a monotone function \( f \) and \( \int f \leq f(b)-f(a) \).
Recommended Books:

1. Royden, L. : Real Analysis (PHI).
2. Goldberg, R. : Methods of Real Analysis.
7. T.M.Apostol : Mathematical Analysis.
COMPLEX ANALYSIS-I

Course No: **MM-CR-203**
Duration of Examination: 2:30 Hrs.
No. of Credits: **04**

Max. Marks: 100
External Exam: 80
Internal Assessment: 20

CREDIT-I
Continuity and differentiability of complex functions, C-R equations and analytic functions. Necessary and sufficient condition for a function to be analytic, Complex integration, Cauchy Goursat theorem, Cauchy’s integral formula, higher order derivatives. Morera’s theorem, Cauchy’s inequality.

CREDIT-II
Liouville’s Theorem and its generalization, Fundamental Theorem of Algebra, Taylor’s Theorem, Maximum Modulus Theorem, Schwarz Lemma and its generalizations, Zeros of an analytic function and their isolated character, Identity Theorem, Argument Principle, Rouche’s Theorem and its applications.

CREDIT-III
Laurent’s Theorem, Classification of Singularities, Removable Singularity, Riemann’s Theorem, Poles and behaviour of a function at a pole, Essential singularity, Casorati-Weiersstrass Theorem on essential singularity, Infinite Products, Convergence and divergence of infinite product, Absolute convergence, Necessary and sufficient conditions for convergence and absolute convergence.

CREDIT-IV
Möbius transformations. Their properties and classification. Fixed Points, Cross Ratio, Inverse points and Critical Points. Conformal Mapping. Linear transformations carry circles to circles and inverse points to inverse points, Mappings of (i) upper half plane on to the unit disc, (ii) unit disc on to the unit disc, (iii) left half plane on to the unit disc and (iv) circle on to a circle. The transformations \( w = z^2 \) and \( w = \frac{1}{2} \left( z + \frac{1}{z} \right) \).
**Recommended Books:**

1. L.Ahlfors, Complex Analysis.
THEORY OF NUMBERS-II

Course No: MM-EA-204 Max. Marks: 100
Duration of Examination: 2:30 Hrs. External Exam: 80
No. of Credits: 04 Internal Assessment: 20

CREDIT-I

Integers belonging to a given exponent mod p and related results. Converse of
Fermat’s Theorem. If \( d/p-1 \), the Congruence \( x^d \equiv 1 \pmod{p} \), has exactly \( d \)-solutions. If any integer belongs to \( t \pmod{p} \), then exactly \( \phi(t) \) incongruent
numbers belong to \( t \pmod{p} \). Primitive roots. There are \( \phi(p-1) \) primitive roots
of a odd prime \( p \). Any power of an odd prime has a primitive root. The function
\( \lambda(m) \) and its properties. \( a^{\lambda(m)} \equiv 1 \pmod{m} \), where \( (a, m)=1 \).There is always an
integer which belongs to \( \lambda(m) \pmod{m} \). Primitive \( \lambda \)-roots of \( m \).The numbers
having primitive roots are 1, 2, 4, \( p^a \) and \( 2p^a \) where \( p \) is an odd prime.

CREDIT-II

Quadratic residues. Euler criterion. The Legendre symbol and its properties.
Lemma of Gauss. If \( p \) is an odd prime and \( (a, 2p)=1 \),
then \( \left( \frac{a}{p} \right) = (-1)^t \) where \( t = \sum_{j=1}^{(p-1)/2} \left[ \frac{ja}{p} \right] \), and \( \left( \frac{2}{p} \right) = (-1)^{(p^2-1)/8} \)

The law of a Quadratic Reciprocity, Characterization of
primes of which 2, -2, 3, -3, 5, 6 and 10 are quadratic residues or non residues.
Jacobi symbol and its properties. The reciprocity law for Jacobi symbol.

CREDIT-III

Number theoretic functions. Some simple properties of \( \tau(n), \sigma(n), \phi(n) \) and \( \mu(n) \).
Mobius inversion formula. Perfect numbers. Necessary and sufficient condition
for an even number to be perfect. The function \( \lfloor x \rfloor \) and its properties. The
symbols “\( O \)”, “\( o \)”, and “\( ~ \)”. Euler’s constant \( \gamma \). The series
\( \sum_{p \leq n} \frac{1}{p} \) diverges. \( \prod_{p \leq n} \frac{1}{p} < 4^n \), for \( n \geq 2 \). Average order of magnitudes of
\( \tau(n), \sigma(n), \phi(n) \). Farey fractions. Rational approximation.
Simple continued fractions. Application of the theory of infinite continued fractions to the approximation of irrationals by rationals. Hurwitz theorem. $\sqrt{5}$ is the best possible constant in the Hurwitz theorem. Relation between Riemann Zeta function and the set of primes. Characters. The L-Function $L(s, \chi)$ and its properties. Dirichlet’s theorem on infinity of primes in an arithmetic progression (its scope as in Leveque’s topics in Number Theory, Vol. II. Chapter VI).

**Recommended Books**


**Suggested Readings:**


2. An introduction to the theory of Numbers by G.H Hardy and Wright.


4. An elementary Number theory of E. Landau.
OPERATIONS RESEARCH

Course No. **MM-EA-205**  
Max. Marks: 100

Duration of Examination: 2:30 Hrs.  
External Exam: 80

No. of Credits: **04**  
Internal Assessment: 20

**CREDIT-I**
Definition of Operational Research, main phases of OR study, Linear programming problems (LPP), applications to industrial problems –optimal product links and activity levels, convex sets and convex functions, simplex method and extreme point theorems. Big M and two phase methods of solving LPP.

**CREDIT-II**
Revised simplex method, Assignment problem, Hungarian method, Transportation problem, and Mathematical formulation of transportation problem, methods of solving (North-West Corner rule, Vogel’s method and U.V. method.) Concept and applications of duality, formulation of dual problem, duality theorems (weak duality and strong duality theorems), dual simplex method, primal- dual relations, complementary slackness theorems and conditions.

**CREDIT-III**
Sensitivity Analysis: changes in the coefficients of the objective function and right hand side constants of constraints, adding a new constraint and a new variable. Project management: PERT and CIM: probability of completing a project.

**CREDIT-IV**
Game theory: Two person zero sum Games, games with pure strategies, Games with mixed strategies, Min. Max. principle, Dominance rule, finding solution of 2 x 2, 2 x m, 2 x m games. Equivalence between game theory and linear programming problem(LPP). Simplex method for game problem.

**Recommended Books:**

FOURIER ANALYSIS

Course No: **MM-EA-206**  
Max. Marks: 100  
Duration of Examination: 2:30 Hrs.  
External Exam: 80  
No. of Credits: **04**  
Internal Assessment: 20

**CREDIT-I**

**Fourier Series**

Motivation and definition of Fourier series, Fourier series over the interval of length $2\pi$, change of the interval, the complex exponential Fourier series, criteria for the convergence of Fourier series, Riemann-Lebesgue lemma, convergence at a point of continuity, convergence at a point of discontinuity, uniform convergence and convergence in mean of the Fourier series.

**CREDIT-II**

**Derivatives and Integrals of Fourier Series**

Differentiation of Fourier series, differentiation of the sine and cosine series, convergence theorems related to the derived Fourier series, integration of Fourier series, applications of Fourier series to Heat flow and Vibrating string problems.

**CREDIT-III**

**The Fourier Transforms**

Definition and examples of Fourier transforms in $L^1(\mathbb{R})$, basic properties of Fourier transforms, Fourier transforms in $L^2(\mathbb{R})$, Convolution theorem, Plancherel’s and Parseval’s formulae, Poisson summation formula, Shannon-Whittaker sampling theorem, Discrete and fast Fourier transforms with examples.
Applications of Fourier Transforms

Application of Fourier transforms to the central limit theorem in mathematical statistics, solution of ordinary differential equations and integral equations using Fourier transforms, applications of Fourier transforms to Dirchilet’s problem in the half-plane, Neumann's problem in the half-plane and Cauchy's problem for the diffusion equation.

Books Recommended:

Text Book:


Reference Books:

LINEAR ALGEBRA

Course No: MM-EA-207  Max. Marks:  50
Duration of Examination: 1:15 Hrs.  External Exam:  40
No. of Credits: 02  Internal Assessment: 10

CREDIT-I

Linear transformation, Algebra of Linear transformations, Linear operators, Invertible linear transformations, Matrix representation of a Linear transformation. Linear Functionals, dual spaces, dual basis, Anhilators, Eigenvalues and eigen-vectors of linear transformation, diagonalization, Similarity of linear transformation.

CREDIT-II


Books Recommended:

1. A first course in linear algebra, Robort A.Beezer.
2. Linear Algebra, John B.Fraleigh and Raymond
4. Linear Algebra, Vivek Sahai and Vikas Bist.
NUMERICAL ANALYSIS

Course No: **MM-EA-208**
Max. Marks: 50

Duration of Examination: 1:15 Hrs.
External Exam: 40

No. of Credits: **02**
Internal Assessment: 10

**CREDIT-I**


**CREDIT-II**


**Books Recommended:**

1. Introduction to Methods of Numerical Analysis by S.S.Sastry.
2. Introduction to Numerical Analysis by Atkinson.
# MATHEMATICAL MODELING

Course No: **MM-EA-209**  
Max. Marks: 50  
Duration of Examination: 1:15 Hrs.  
External Exam: 40  
No. of Credits: **02**  
Internal Assessment: 10

## CREDIT-I

Introduction to Mathematical Modeling, Types of Modeling, Classification of Mathematical models, Formulation, Solution and Interpretation of a Model. Linear growth and decay models, non-linear growth and decay models, continuous population models for single species, delay models, Logistic growth model, Discrete models, Age structured populations, Fibonacci’s rabbits, the Golden ratio, Fishery management model, Compartment models, limitations of mathematical models.

## CREDIT-II


## Books Recommended

5. M. R. Cullen, Linear Models in Biology, Ellis Horwood Ltd.
6. Jaffrey R. Chasnov, Mathematical Biology, Hong Kong Press.
INTEGRAL EQUATIONS

Course No: **MM-EA-210**  Max. Marks: 50
Duration of Examination: 1:15 Hrs.  External Exam: 40
No. of Credits: **02**  Internal Assessment: 10

**CREDIT-I**

Linear Integral Equations of the First and Second kinds, Volterra and Fredholm Integral Equations, Relations Between Differential and Integral Equations, Solution of Volterra and Fredholm Integral Equations by the Methods of Successive Substitutions and Successive Approximations, Iterated and Resolvent Kernels, Neumann Series Reciprocal Functions, Volterra’s Solutions of Fredholm Equations.

**CREDIT-II**


**Books Recommended:**


**Reference Books:**

OPEN ELECTIVE

Course No: MM-EO-211  Max. Marks: 100
Duration of Examination: 2:30 Hrs.  External Exam: 80
No. of Credits: 04  Internal Assessment: 20
SEMESTER-III

ORDINARY DIFFERENTIAL EQUATIONS

Course No: **MM-CR-301**  
Max. Marks: 100
Duration of Examination: 2:30 Hrs.  
External Exam: 80
No. of Credits: **04**  
Internal Assessment: 20

**CREDIT-I**


**CREDIT-II**

Solution in Series: (i) Roots of an Indicial equation, un-equal and differing by a quantity not an integer. (ii) Roots of an Indicial equation, which are equal. (iii) Roots of an Indicial equation differing by an integer making a coefficient infinite. (iv) Roots of an Indicial equation differing by an integer making a coefficient indeterminate.

Simultaneous equation \( \frac{dx}{P} = \frac{dy}{Q} = \frac{dz}{R} \) and its solutions by use of multipliers and a second integral found by the help of first. Total differential equations \( Pdx + Qdy + Rdz = 0 \). Necessary and sufficient condition that an equation may be integrable. Geometric interpretation of the \( Pdx + Qdy + Rdz = 0 \).

**CREDIT-III**

CREDIT-IV


**Recommended Books:**


COMPLEX ANALYSIS-II

Course No: **MM-CR-302**
Duration of Examination: 2:30 Hrs.
No. of Credits: **04**

Max. Marks: 100
External Exam: 80
Internal Assessment: 20

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**CREDIT-I**

Calculus of Residues, Cauchy’s residue theorem, Evaluation of integrals by the method of residues, Parseval’s Identity, Branches of many-valued functions with special reference to \( \arg(z) \), \( \log z \) and \( z^n \), Blaschke’s theorem i.e., if \( f(z) \) is analytic and bounded by 1 in \( |z| \leq 1 \) and vanishes at \( z = z_n, n = 1, 2, \ldots \), \( |z_n| \leq 1 \), then
\[
\sum (1 - |z_n|) \text{ is convergent or else } f(z) \equiv 0.
\]

**CREDIT-II**

Poisson integral formula for circle and half plane, Poisson-Jensen formula, Estermann’s uniqueness theorem, Carlemann’s theorem and the uniqueness theorem associated with it, Hadamard’s three circle theorem, \( \log M(r) \) and \( \log I_2(r) \) as convex functions of \( \log r \), Theorem of Borel and Caratheodory.

**CREDIT-III**

Power series: Cauchy-Hadamard formula for the radius of convergence, Picad’s theorem on power series: If \( a_n > a_{n+1} \) and \( \lim a_n = 0 \), then the series \( \sum a_n z^n \) has radius of convergence equal to 1 and the series converges for \( |z| = 1 \) except possibly at \( z = 1 \), A power series represents an analytic function within the circle of convergence, Hadamard-Pringsheim theorem. The principle of analytic continuation, uniqueness of analytic continuation, Power series method of analytic continuation, functions with natural boundaries e.g., \( \sum z^n \), \( \sum z^{-n} \), Schwarz reflection principle.
Functions with positive real part, Borel’s theorem: If \( f(z) = 1 + \sum a_n z^n \) is analytic and has a positive real part in \( |z| < 1 \), then \( |a_n| \leq 2 \), Univalent functions, Area theorem, Bieberbach’s conjecture (statement only) and Koebe’s \( \frac{1}{4} \) theorem.

Space of Analytic Functions, Bloch’s Theorem, Schottky’s theorem, \( a \) - points of an analytic function, Picard’s theorem viz, an integral function which is not a constant takes every value with one possible exception, Landau’s theorem.

**Recommended Books:**

1. L.V. Ahlfors, Complex Analysis
2. E. C. Titchmarsh, Theory of Functions
3. J. B. Conway, Functions of a Complex Variable-I
4. Richard Silverman, Complex Analysis
5. Z. Nehari, Conformal Mappings
6. A.I. Markushevish, Theory of Functions of a Complex Variable
FUNCTIONAL ANALYSIS-I

Course No: MM-CR-303  Max. Marks: 100
Duration of Examination: 2:30 Hrs.  External Exam: 80
No. of Credits: 04  Internal Assessment: 20

BANACH SPACE:

CREDIT-I

Banach Spaces: Definition and examples, subspaces, quotient spaces, Continuous Linear Operators and their Characterization, Completeness of the space L( X,Y ) of bounded linear operators (and its converse), incompleteness of C[ a, b ], under the integral norm, Finite dimensional Banach spaces, Equivalence of norms on finite dimensional space and its consequences, Dual of a normed linear space, Hahn Banach theorem (extension form) and its applications, Complemented subspaces, Duals of l_p^n, C_0, l_p (p≥1), C[ a, b ].

CREDIT-II

Uniform boundedness Principle and weak boundedness, Dimension of an ∞-dimensional Banach space, Conjugate of a continuous linear operator and its properties, Banach-Steinhauss theorem, open Mapping and closed graph theorems, counterexamples to Banach-Steinhauss, open mapping theorem and closed graph theorems for incomplete domain and range spaces, separable Banach spaces and the separability of some concrete Banach spaces (C_0, C[ 0,1 ], l_p, p≥1 ), Reflexive Banach Spaces, closed subspace and the dual of a reflexive Banach space, Examples of reflexive and non-reflexive Banach spaces.

HILBERT SPACE:

CREDIT-III

Hilbert spaces: Definition and examples, Cauchy’s Schwartz inequality, Parallogram law, orthonormal (o.n) systems, Bessel’s inequality and Parseval’s Identity for complete orthonormal systems, Riesz-Fischer theorem, Gram Schmidt process, o.n basis in separable Hilbert spaces.
CREDIT-IV


Recommended Books:

ABSTRACT MEASURE THEORY

Course No. MM-EA-304
Duration of Examination: 2:30 Hrs.
No. of Credits: 04

Max. Marks: 100
External Exam: 80
Internal Assessment: 20

CREDIT-I
Semiring, algebra and $\sigma$- algebra of sets, Borel sets, measures on semirings, outer measure associated with a set function and basic properties, measurable sets associated with an outer measure as a $\sigma$- algebra, construction of the Lebesgue measure on $\mathbb{R}^n$.

CREDIT-II
For $f \in L^1[a, b]$, $F/ = f$ a.e. on $[a, b]$. If $f$ is absolutely continuous on $(a, b)$ with $f(x)=0$ a.e, then $f = \text{constant}$. Characterization of an absolutely continuous function as an indefinite Lebesgue integral. Non-Lebesgue integrability of $f$ where $f(x) = \frac{x^2}{2}\sin(1/x^2)$, $f(0) = 0$ on $[0, 1]$. Fundamental theorem of calculus for the Lebesgue integral. A brief introduction to $L_p$ spaces. Holder’s and Minkowki’s inequalities.

CREDIT-III
Improper Riemann integral as a Lebesgue integral, calculation of some improper Riemann integrable functions, space of Lebesgue integrable functions as completion of Riemann integrable functions on $[a, b]$, change of variables formula and simple consequences, Riemann Lebesgue lemma.

CREDIT-IV
Product measures and iterated integrals, example of non-integrable functions whose iterated integrals exist (and are equal), Fubini theorem, expressing a double integral as an iterated integral, Tonelli-Hobson theorem as a converse to Fubini theorem, differentiation under the integral sign.

Recommended Books:
1. C.D.Aliprantis and O.Burkinshaw, Principles of Real Analysis
2. Goldberg , R. : Methods of Real Analysis
3. T.M.Apostol : Mathematical Analysis
**Suggested Readings:**
1. Royden, L: Real Analysis (PHI)
2. Chae, S.B. Lebesgue Integration (Springer Verlag).
4. Barra, De, G.: Measure theory and Integration (Narosa)
ADVANCED GRAPH THEORY

Course No: **MM-EA-305**  
Max. Marks: **100**  
Duration of Examination: **2:30** Hrs.  
External Exam: **80**  
No. of Credits: **04**  
Internal Assessment: **20**

**CREDIT-I**

**Colorings**

Vertex coloring, chromatic number $\chi(G)$, bounds for $\chi(G)$, Brook’s theorem, edge coloring, Vizing’s theorem, map coloring, six color theorem, five color theorem, every graph is four colourable iff every cubic bridgeless plane map is 4-colorable, every planar graph is 4-colorable iff $\chi'(G)=3$, Heawood map-coloring theorem, uniquely colorable graphs

**CREDIT-II**

**Matchings**

Matchings and 1-factors, Berge’s theorem, Hall’s theorem, 1-factor theorem of Tutte, antifactor sets, $f$-factor theorem, $f$-factor theorem implies 1-factor theorem, Erdos- Gallai theorem follows from $f$-factor theorem, degree factors, $k$-factor theorem, factorization of $K_n$.

**CREDIT-III**

**Edge graphs and eccentricity sequences**

Edge graphs, Whitney’s theorem on edge graphs, Beineke’s theorem, edge graphs of trees, edge graphs and traversibility, total graphs, eccentricity sequences and sets, Lesniak theorem for trees, construction of trees, neighbourhoods, Lesniak theorem graphs.

**CREDIT-IV**

**Groups in graphs and Graph networks**

Automorphism groups of graphs, graph with a given group, Frucht’s theorem, Cayley digraph, Transport networks, maximum flow cut and its capacity, Max-flow-Min-cut theorem, multiple sources and sinks, networks containing undirected edges, lower bounds on edge flows, topological sorting, critical path, graphs in game theory, kernel of a digraph
References

1. R. Balakrishnan, K. Ranganathan, A Text Book of Graph Theory, Springer-Verlag, New York
2. B. Bollobas, Extremal Graph Theory, Academic Press,
3. F. Harary, Graph Theory, Addison-Wesley
4. Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice Hall
5. S. Pirzada, An Introduction to Graph Theory, Universities Press, OrientBlackswan, 2012
6. W. T. Tutte, Graph Theory, Cambridge University Press
7. D. B. West, Introduction to Graph Theory, Prentice Hall
Course No. **MM-EA-306**
Duration of Examination: 2:30 Hrs.
No. of Credits: **04**

Max. Marks: 100
External Exam: 80
Internal Assessment: 20

**CREDIT-I**

Diffusion in biology: Fick’s law of diffusion, Fick’s perfusion law, membrane transport, diffusion through a slab, convective transport, Trancapillary exchange; Heat transport in biological tissues, Oxygen transport through red cells, Gas exchange in lungs, the ideal gas law and solubility of gases, the equation of gas transport in one Alveolus.

**CREDIT-II**

Biofluid mechanics: Introduction, various types of fluid flows, viscosity, basic equation of fluid, mechanics, continuity equation, equation of motion, the circulatory system, systemic and pulmonary circulation, the circulation in heart, blood composition, arteries and arterioles, models in blood flow, Poiseulle’s flow and its applications, the pulse wave.

**CREDIT-III**

Tracers in physiological systems: Compartment systems, the one compartment system, Discrete and continuous transfers, ecomatrix, the continuous infusion, the two compartment system, Bath-tub models, three-compartment system, the leaky compartment and the closed systems, elementary pharmacokinetics, parameter estimation in two compartment models, basic introduction to n-compartment systems.

**CREDIT-IV**

**Books Recommended**

5. J.R. Chesnov, *Lecture notes in Mathematical Biology*, Hong Kong Press
CREDIT-I

Time Frequency Analysis and Wavelet Transforms

Gabor transforms basic properties of Gabor transforms, continuous and discrete wavelet transforms with examples, basic properties of wavelet transforms, examples of Haar wavelet, Mexican hat wavelet and their Fourier transforms, dyadic orthonormal wavelet bases for $L^2(\mathbb{R})$.

CREDIT-II

Multiresolution Analysis and Construction of Wavelets

Definition and examples of multiresolution analysis (MRA), properties of scaling functions and orthonormal wavelet bases, construction of orthonormal wavelets with special reference to Haar wavelet, Franklin wavelet and Battle-Lemarie wavelet, Spline wavelets, construction of compactly supported wavelets, Daubechie's wavelets and algorithms.

CREDIT-III

Other Wavelet Constructions and Characterizations

Introduction to basic equations, some applications of basic equations, characterization of MRA wavelets and scaling functions, construction of biorthogonal wavelets, wavelet packets, definition and examples of wavelets in higher dimensions.
Further Extensions of Multiresolution Analysis

Periodic multiresolution analysis and the construction of periodic wavelets, multiresolution analysis associated with integer dilation factor (M-band wavelets), harmonic wavelets, properties of harmonic scaling functions.

Books Recommended

Text Book:


Reference Books:

Course No. **MM-EO-308**  
Duration of Examination: 2:30 Hrs.  
No. of Credits: **04**  

**Max. Marks:** 100  
**External Exam:** 80  
**Internal Assessment:** 20
SEMESTER-IV
PARTIAL DIFFERENTIAL EQUATIONS

Course No: MM-CR-401  Max. Marks: 100
Duration of Examination: 2:30 Hrs.  External Exam: 80
No. of Credits: 04  Internal Assessment: 20

CREDIT-I

Introduction to partial differential equations; partial differential equations of first order; linear and non-linear partial differential equations; Lagrange’s method for the solution of linear partial differential equations; Charpits method and Jacobi methods for the solution of non-linear partial differential equations; Initial-value problems for Quasi-linear first-order equations; Cauchy’s method of characteristics.

CREDIT-II

Origin of second order partial differential equations; linear partial differential equations with constant coefficients; Methods for solution second order partial differential equations; classification of second order partial differential equations; canonical forms; adjoint operators; Riemann’s method; Monge’s method for the solution of non-linear partial differential equations.

CREDIT-III

Derivation of Laplace and Heat equations; Boundary value problems; Drichlet’s and Neumann problems for a circle and sphere; Solutions by separation of variables method; cylindrical coordinates and spherical polar coordinate system; Maximum-Minimum principle; Uniqueness theorem; Sturm-Liouville Theory.

CREDIT-IV

Derivation of wave equation; D’Alembert’s solution of one dimensional wave equation; Separation of variables method; periodic solutions; method of eigen functions; Duhamel’s principle for wave equation; Laplace and Fourier transforms and their applications to partial differential equations; Green function method and its applications.
References

2. L.C. Evans; Partial Differential Equations, GTM, AMS, 1998
DIFFERENTIAL GEOMETRY

Course No: MM-CR-402  Max. Marks: 100
Duration of Examination: 2:30 Hrs.  External Exam: 80
No. of Credits: 04  Internal Assessment: 20

CREDIT-I


CREDIT-II

Surfaces; Regular surfaces with examples, coordinate charts or curvilinear coordinates, change of coordinates, tangent plane at a regular point, normal to the surface, orient able surface, differentiable mapping between regular surfaces and their differential. Fundamental form or a metric of a surface, line element, invariance of a line element under change of coordinates, angle between two curves, condition of orthogonality of coordinate curves. Area of bounded region, invariance of area under change of coordinates.

CREDIT-III

Christoffel symbols. Expressing Christoffel symbols in terms of metric coefficients and their derivative. Theorema egerium (Gaussian curvature is intrinsic). Isometric surfaces have same Gaussian curvatures at corresponding points. Gauss equations and Manardi Codazzi equations for surfaces. Fundamental theorem for regular surface. (Statement only). Geodesics: Geodesic curvature, Geodesic curvature is intrinsic, Equations of Geodesic, Geodesic on sphere and pseudo sphere. Geodesic as distance minimizing curves. Gauss-Bonnet theorem (statement only). Geodesic triangle on sphere. Implication of Gauss-Bonnet theorem for Geodesic triangle.

**Recommended Books:**


**Suggested Readings:**

1. W. Klingenberg: A course in Differential Geometry (Spring Verlag)
2. C.E. Weatherburn: Differential Geometry of Three dimensions.
3. T. Willmore : An Introduction to Differential Geometry
4. J. M. Lee : Riemannian Manifolds, An Introduction to Curvature (Spri
ADVANCED ABSTRACT ALGEBRA—II

Course No: MM-CR-403  Max. Marks: 100
Duration of Examination: 2:30 Hrs.  External Exam: 80
No. of Credits: 04  Internal Assessment: 20

CREDIT-I
Relation and Ordering, partially ordered sets, Lattices, properties of Lattices, Lattices as algebraic Systems, sub-lattices, direct product and homomorphism, Modular Lattices, complete Lattices, bounds of Lattices, Distributive Lattice, Complemented Lattices.

CREDIT-II

CREDIT-III
Fields: Prime fields and their structure, Extensions of fields, Algebraic numbers and Algebraic extensions of a field, Roots of polynomials, Remainder and Factor theorems, Splitting field of a polynomial, Existence and uniqueness of splitting fields of polynomials, Simple extension of a field.

CREDIT-IV
Separable and In-separable extensions, The primitive element theorem, Finite fields, Perfect fields, The elements of Galois theory. Automorphisms of fields, Normal extensions, Fundamental theorem of Galois theory, Construction with straight edge and compass, $\mathbb{R}^n$ is a field iff $n = 1, 2$.

Recommended Books:
1. I.N.Heristein : Topics in Algebra.
ANALYTIC THEORY OF POLYNOMIALS

Course No: **MM-EA-404**
Max. Marks: 100
Duration of Examination: 2:30 Hrs.
External Exam: 80
No. of Credits: **04**
Internal Assessment: 20

**CREDIT-I**


**CREDIT-II**

Critical points in terms of zeros, Fundamental results and critical points, Convex Hulls and Gauss-Lucas theorem, Some applications of Gauss-Lucas theorem. Extensions of Gauss-Lucas theorem, Average distance from a line or a point. Real polynomials and Jenson’s theorem, Extensions of Jenson’s theorem.

**CREDIT-III**

Derivative estimates on the unit interval, Inequalities of S. Bernstein and A. Markov, Extensions of higher order derivatives, Two other extensions, Dependence of the bounds on the zeros, Some special classes, $L^p$ analogous of Markov’s inequality.

**CREDIT-IV**

Coefficient Estimates, Polynomials on the unit circles. Coefficients of real trigonometric polynomials. Polynomials on the unit interval.
**Recommended Books:**


2. Geometry of polynomials by Morris Marden.

3. Topics in polynomials :extremal properties, problems, inequalities, zeroes by

4. G.V. Milovanovic, D.S. Mitrinovic and Th. M. Rassias

Mathematical Statistics

Course No: **MM-EA-405**
Max. Marks: 100
Duration of Examination: 2:30 Hrs.
External Exam: 80
No. of Credits: **04**
Internal Assessment: 20

**Credit-I**

Some Special Distributions, Bernoulli, Binomial, Trinomial, Multinomial, Negative Binomial, Poisson, Gamma, Chi-square, Beta, Cauchy, Exponential, Geometric, Normal and Bivariate Normal Distributions.

**Credit-II**

Distribution of Functions of Random Variables, Distribution Function Method, Change of Variables Method, Moment generating function Method, t and F Distributions, Dirichelet Distribution, Distribution of Order Statistics, Distribution of $X$ and $\frac{nS^2}{\sigma^2}$, Limiting distributions, Different modes of convergence, Central Limit theorem.

**Credit-III**

Interval Estimation, Confidence Interval for mean, Confidence Interval for Variance, Confidence Interval for difference of means and Confidence interval for the ratio of variances. Point Estimation, Sufficient Statistics, Fisher-Neyman criterion, Factorization Theorem, Rao-Blackwell Theorem, Best Statistic (MvUE), Complete Sufficient Statistic, Exponential class of pdfs.

**Credit-IV**

Rao-Crammer Inequality, Efficient and Consistent Estimators, Maximum Likelihood Estimators (MLE’s). Testing of Hypotheses, Definitions and examples, Best or Most powerful (MP) tests, Neyman Pearson theorem, Uniformly most powerful (UMP) Tests, Likelihood Ratio Test, Chi-square Test.
**Recommended Books**

1. Hogg and Craig : An Introduction to Mathematical Statistics  

**Suggested Readings:**

1. C.R.Rao : Linear Statistical Inference and its Applications  
FUNCTIONAL ANALYSIS-II

Course No. **MM-WA-406**
Max. Marks: 100
Duration of Examination: 2:30 Hrs. External Exam: 80
No. of Credits: **04** Internal Assessment: 20

<table>
<thead>
<tr>
<th>CREDIT-I</th>
<th>Relationship between analytic and geometric forms of Hahn-Banach Theorem, Applications of Hahn-Banach Theorem: Banach limits, Markov-Kakutani theorem for a commuting family of maps, Complemented subspaces of Banach spaces, Complementability of dual of a Banach space in its bidual, uncomplementability of co in $l_\infty$.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CREDIT-II</td>
<td>Dual of Subspaces, Quotient spaces of a normed linaedr space. Weak and Weak* topologies on a Banach space, Goldstine’s theorem, Banach Alaoglu theorem and its simple consequences. Banch’s closed range theorem, injective and surjective bounded linear mappings between Banach spaces.</td>
</tr>
<tr>
<td>CREDIT-III</td>
<td>$l_\infty$ and $C[0,1]$ as universal separable Banach spaces, $l_1$ as quotient universal separable Banach spaces, Reflexivity of Banach spaces and weak compactness, Completeness of $L^p[a,b]$. Extreme points, Krein-Milman theorem and its simple consequences.</td>
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<td>CREDIT-IV</td>
<td>Dual of $l_\infty$, $C(X)$ and $L_p$ spaces. Mazur-Ulam theorem on isometries between real normed spaces, Muntz theorem in $C[a,b]$.</td>
</tr>
</tbody>
</table>

**Recommended Books:**

1. J. B. Conway; A First Course in Functional Analysis (Springer Verlag).
2. R.E. Megginson; An Introduction to Banach Space theory (Springer Verlag, GTM, Vol. 183)

**Reference Books:**

1. Ballobas, B; Linear Analysis (Camb. Univ.Pres)
2. Beauzamy, B; Introduction to Banach Spaces and their geometry (North Holland).
NON LINEAR ANALYSIS

Course No: MM-EA-407
Duration of Examination: 1:15 Hrs.
No. of Credits: 04

Max. Marks: 100
External Exam: 80
Internal Assessment: 20

CREDIT-I


CREDIT-II

Gateaux Derivative, Frechet Derivative, Lower semicontinuous Convex Functions, Subdifferential of Convex Functions, Directional Derivatives, Characterization of Convexity and Strict Convexity, Directional Derivatives and Subgradients, Gateaux and Frechet Differentiability, Differentiability and Continuity

CREDIT-III

Monotone Operators, Strong Notions of Monotonicity such as Para, Cyclic, Strict, Uniform and Strong Monotonicity, Maximal Monotone Operator and their Properties, Bivariate Functions and Maximal Monotonicity, Debrunner-Flor Theorem, Minty Theorem, Rockfeller’s Cyclic Monotonicity Theorem, Monotone Operators on R.

CREDIT-III

Reisz-Representation Theorem, Projection Mappings and their Properties, Characterization of Projection onto Convex sets and their Geometrical Interpretation,

**Book Recommended:**


**Reference Book:**

ADVANCED TOPICS IN TOPOLOGY AND MODERN ANALYSIS

Course No. **MM-EA-408**  
Duration of Examination: 2:30 Hrs.  
No. of Credits: **04**  
Max. Marks: 100  
External Exam: 80  
Internal Assessment: 20

**CREDIT-I**

Uniform spaces. Definition and examples, uniform topology, and metrizability complete regularity of uniform spaces, pre-compactness and compactness in uniform spaces, uniform continuity.

**CREDIT-II**

Uniform continuity, uniform continuous maps on compact spaces Cauchy convergence and completeness in uniform spaces, initial uniformity, simple applications to function spaces, Arzela- Ascoli theorem.

**CREDIT-III**

Abstract Harmonic Analysis, Definition of a topological group and its basic properties. Subgroups and quotient groups. Product groups and projective limits. Properties of topological groups involving connectedness. Invariant metrics and Kakutani theorem, Structure theory for compact and locally compact Abelian groups.

**CREDIT-IV**

Some special theory for compact and locally compact Abelian groups, Haar integral and Haar measure, invariant means defined for all bounded functions, convolution of functions and measures. Elements of representation theory, Unitary representations of locally compact groups.

**Recommended Books:**

1. I.M. James Uniform Spaces, Springer Verlag.
**Suggested Readings:**

1. G. Murdeshwar, General Topology,

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<tr>
<th>Course No: <strong>MM-EA-409</strong></th>
<th>Max. Marks: 100</th>
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<td>Duration of Examination: 2:30 Hrs.</td>
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