# MAA VINDHYAVASINI UNIVERSITY, MIRZAPUR

## DEPARTMENT OF MATHEMATICS

**National Education Policy-2020**

**Choice Based Credit System (CBCS)**

**Syllabus**

**of**

**MATHEMATICS**

**For**

**One Year PG Programme**

**(Semester IX & X)**

**(Effective from Academic Session 2026-2027)**

Dean
Faculty of Science And Technology
Maa Vindhyavasini University, Mirzapur

# MAA VINDHYAVASINI UNIVERSITY, MIRZAPUR

## DEPARTMENT OF MATHEMATICS

### National Education Policy-2020

### Syllabus of One Year PG (Mathematics) Programme Designed by

| Sr. No. | Name | Designation | University/College | Signature |
|---|---|---|---|---|
| 01 | Prof. Devendra Pandey | Professor/Dean | K.B.P.G. College, Mirzapur | |
| 02 | Dr. Neelam Yadav | Assistant Professor | N.S.P.S. Government P.G. College, Magaraha, Mirzapur | |
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Dean
Faculty of Science And Technology
Maa Vindhyavasini University, Mirzapur

# One Year PG (Mathematics) Programme

## Based on

## National Education Policy-2020

## In

## Choice Based Credit System (CBCS)

The proposed curriculum is designed to provide students with a comprehensive understanding of Mathematics and its diverse applications. It aims to develop not only a strong foundation in important mathematical concepts and techniques but also the ability to apply commonly used mathematical methods to various fields and real-life problems. Through this curriculum, students will enhance their analytical, logical, and problem-solving skills, enabling them to use mathematical tools effectively in interdisciplinary contexts.

### Subject Prerequisites

To study this subject, a student must have B.A./B.Sc. Honors / B.A./B.Sc. Honors with Research in Mathematics or its equivalent examination from a recognized board or institution.

### Eligibility for Admission

For admission to the One Year Postgraduate Programme in Mathematics, candidates must have passed B.A./B.Sc. Honors / B.A./B.Sc. Honors with Research in Mathematics or an equivalent examination with Mathematics as one of the main subjects from a recognized board/institution, subject to the rules and regulations of the university.

### Programme Duration

The duration of the One Year Postgraduate Programme in Mathematics shall be one academic year consisting of two semesters. Candidates admitted to Semester-IX will undergo the programme over this period. The session shall comprise two regular semesters.

## Examination and Assessment

| Suggested Internal Continuous Evaluation / Examination Methods (Max. Marks: 25) (Except Research Project) | | | |
|---|---|---|---|
| | | **Max. Marks** | |
| **Sr. No.** | **Assessment Type** | **Regular** | **Private** |
| 01 | Class Test | 10 | 15 |
| 02 | Punctuality / Regularity | 10 | --- |
| 03 | Presentation / Research Oriented Assignment | 5 | 10 |
| **External Examination Methods (Max. Marks: 75)** | | | |
| As prescribed by the University (as per common ordinance for examination and assessment). | | | |



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**Programme Specific Outcomes (PSOs)**

**PSO1:** To develop a deep understanding of the fundamental axioms of Mathematics and the ability to build mathematical ideas and logical reasoning based on them.

**PSO2:** To provide advanced knowledge in areas of Pure Mathematics, particularly Analysis and Geometry, thereby enabling students to pursue higher studies and research in these fields.

**PSO3:** To develop an understanding of Applied Mathematics and motivate students to use mathematical techniques as effective tools in the study of other scientific disciplines.

**PSO4:** To encourage students to undertake research studies in Mathematics and related interdisciplinary areas.

**PSO5:** To provide students with diverse career opportunities, including research, teaching, banking, and other professional fields where mathematical and analytical skills are highly valued.

**PSO6:** To inculcate problem-solving ability, critical thinking, and creativity through presentations, assignments, seminars, and project work.

**PSO7:** To support students in preparing for competitive examinations such as CSIR-NET, GATE, and other related examinations through guidance, counselling, and academic resources.

**PSO8:** To nurture lifelong learners who can independently enhance and expand their mathematical knowledge and expertise whenever required.

## Program Structure

The One-Year Postgraduate Programme in Mathematics is designed under the Choice Based Credit System (CBCS) with a minimum requirement of 40 credits distributed over two semesters. The programme comprises a total of 15 courses, systematically spread across the two semesters to ensure balanced academic progression.

The courses are categorized into three components:

1. **Core/Major Courses** – These courses provide fundamental and advanced knowledge in Mathematics, with each course carrying 4 credits.
2. **Discipline Specific Elective (DSE)/Elective Courses** – These courses offer specialized and interdisciplinary learning opportunities according to students' interests, with each course carrying 4 credits.
3. **Dissertation/Research Project/Project Work** – This component is intended to promote research aptitude, analytical thinking, and practical application of mathematical concepts, carrying 4 credits.

**NUMBER OF COURSES AND CREDITS**

| S. No. | Types of course | Credit per course | Total Number of course type | Total credit for the particular type |
|---|---|---|---|---|
| 1 | Core | 4+0 | 3 | 12 |
| 2 | Discipline Specific Elective | 4+0 | 5 | 20 |
| 3 | Dissertation/Research Project/ Project | 0+4 | 2 | 8 |
| **Total** | | | | **40** |

## SEMESTER WISE BREAK-UP OF COURSES

| S. No | Types of course | Semester IX | Semester X | Total |
|---|---|---|---|---|
| 1 | Core | 2(8) | 1(4) | 12 |
| 2 | Discipline Specific Elective | 2(8) | 3(12) | 20 |
| 3 | Dissertation / Research Project/ Project | 1(4) | 1(4) | 8 |
| **Total** | | **2+2+1(20)** | **1+3+1(20)** | **10(40)** |
| | | **40** | | |

## COURSE STRUCTURE: IX-SEMESTER

| Course Code | Course Title | Credits | Marks |
|---|---|---|---|
| **Core/Major Courses** | | | |
| **MC0101T** | Measure and Integration | **4+0** | **75+25** |
| **MC0102T** | Advanced Linear Algebra | **4+0** | **75+25** |
| **Open Elective Courses (Any Two of the Following)** | | | |
| **ME0103T** | Operations Research-II | **4+0 & 4+0** | **75+25 & 75+25** |
| **ME0104T** | Non-linear Analysis | | |
| **ME0105T** | Number Theory and Cryptography | | |
| **ME0106T** | Differential Geometry | | |
| **Project** | | | |
| **MP0107R** | Research Project | **0+4** | **100** |
| | **Total Credits** | **20** | |

## COURSE STRUCTURE: X-SEMESTER

| Course Code | Course Title | Credits | Marks |
|---|---|---|---|
| **Core/Major Courses** | | | |
| **MC0201T** | Functional Analysis | **4+0** | **75+25** |
| **Open Elective Courses (Any Three of the Following)** | | | |
| **ME0202T** | Normed Linear Space and Theory of Integration | **4+0 & 4+0 & 4+0** | **75+25 & 75+25 & 75+25** |
| **ME0203T** | Module Theory | | |
| **ME0204T** | Discrete Mathematics | | |
| **ME0205T** | Differential Geometry of Manifolds | | |
| **ME0206T** | Mathematical Modeling | | |
| **ME0207T** | Operator Theory | | |
| **Project** | | | |
| **MP0208R** | Research Project | **0+4** | **100** |
| | **Total Credits** | **20** | |
| | **Total Credits (IX-Semester)** | **20** | |
| | **Total Credits (IX+X)** | **40** | |

# PG MATHEMATICS (SEMESTER-IX)

## MEASURE AND INTEGRATION

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** IX |
| **Subject:** MATHEMATICS | | |
| **Course Code:** MC0101T | **Course Title:** MEASURE AND INTEGRATION | |
| **Credits:** 4+0 | Core Compulsory | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives:** The main objectives of this course is to

1. introduce the fundamental concepts of semi-algebras, algebras, monotone classes, σ-algebras, measures, and outer measures.
2. study Lebesgue measure, measurable sets, Borel sets, Cantor set, and non-measurable sets on **R**.
3. develop understanding of measurable functions, simple functions, and Lebesgue integration theory.
4. study important convergence theorems and compare Riemann and Lebesgue integrals.

| Unit | Topics |
|---|---|
| | **MEASURE AND INTEGRATION** |
| I | Semi-algebras, algebras, monotone class, σ -algebras, measure and outer measures, Caratheödory extension process of extending a measure on a semi-algebra to generated σ -algebra, completion of a measure space. |
| II | Borel sets, Lebesgue outer measure and Lebesgue measure on R, translation invariance of Lebesgue measure, existence of a non-measurable set, characterizations of Lebesgue measurable sets, the Cantor's set, Non-measurable sets. |
| III | Measurable functions on a measure space and their properties, Borel and Lebesgue measurable functions, simple functions and their integrals, Lebesgue integral on R and its properties, Riemann and Lebesgue integrals. |
| IV | Bounded convergence theorem, Fatou's lemma, Lebesgue monotone convergence theorem, Lebesgue dominated convergence theorem. |

**Course Learning Outcomes:** After studying this course the student will be able to

**CO1:** verify whether a given subset of real valued function is measurable.

**CO2:** understand the requirement and the concept of the Lebesgue integral (a generalization of the Reimann integration) along its properties and relationship between Lebesgue and Riemann integral.

**CO3:** know about the concepts of functions of bounded variations and the absolute continuity of functions with their relations. Extend the concept of outer measure in an abstract space and integration with respect to a measure.

**CO4:** learn and apply Holder and Minkowski inequalities in -spaces and understand completeness of spaces and convergence in measures.

**Books Recommended:**


1. G. de Barra, Measure Theory and Integration, New Age International Ltd., New Delhi, 2014.
2. M. Capinski and P.E. Kopp, Measure, Integral and Probability, Springer, 2005.
3. E. Hewitt and K. Stromberg, Real and Abstract Analysis: A Modern Treatment of the Theory of Functions of a Real Variable, Springer, Berlin, 1975.
4. H.L. Royden and P.M. Fitzpatrick, Real Analysis, Fourth Edition, Pearson, 2015.
5. Walter Rudin, Principle of Mathematical Analysis (3rd edition) McGraw-Hill Kogakusha, International Student Edition, 1976.
6. P. R. Halmos, Measure Theory, Van Nostrand, 1950.
7. P. K. Jain and V. P. Gupta, Lebesgue Measure and Integration, New Age International, New Delhi, 2000.
8. R. G. Bartle, The Elements of Integration, John Wiley, 1966

# PG MATHEMATICS (SEMESTER-IX)

## ADVANCED LINEAR ALGEBRA

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** IX |
| **Subject:** MATHEMATICS | | |
| **Course Code:** MC0102T | **Course Title:** ADVANCED LINEAR ALGEBRA | |
| **Credits:** 4+0 | Core Compulsory | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives**

1. To introduce the concepts of inner product spaces, orthogonality, orthonormal basis, and fundamental inequalities such as Cauchy–Schwarz and Bessel's inequality.
2. To develop understanding of linear transformations through eigenvalues, eigenvectors, eigenspaces, and their role in matrix diagonalization.
3. To study advanced theoretical tools such as Cayley–Hamilton theorem, minimal polynomials, invariant subspaces, and diagonalizability criteria.
4. To provide knowledge of advanced matrix structures including Jordan canonical form, rational canonical form, projections, invariant decompositions, and quadratic forms.

| Unit | Topics |
|---|---|
| | **ADVANCED LINEAR ALGEBRA** |
| I | Inner product spaces, Cauchy-Schwarz inequality, orthogonal vectors, Orthonormal basis, Bessel's inequality, Gram-Schmidt orthogonalization process, Eigenvalues, eigenvectors, and eigenspaces, Algebraic and geometric multiplicities of eigenvalues. |
| II | Diagonalization, Cayley-Hamilton theorem, Invariant subspaces, T-conductors and T-annihilators, Minimal polynomials of linear operators and matrices, Characterization of diagonalizability in terms of multiplicities and also in terms of the minimal polynomial, Triangulability. |
| III | Projections, Invariant direct sums, Characterization of diagonalizability in terms of projections, Primary decomposition theorem. |
| IV | Diagonalizable and nilpotent parts of a linear operator, Rational canonical form of matrices, Elementary Jordan matrices, Reduction to Jordan canonical form, Quadratic form. |

**Course Learning Outcomes (COs)**

**CO1:** Understand and apply the concepts of inner product spaces, including Cauchy–Schwarz inequality, orthogonality, orthonormal basis, Gram–Schmidt process, and Bessel's inequality.

**CO2:** Analyze eigenvalues, eigenvectors, eigenspaces, and study algebraic and geometric multiplicities along with diagonalization of matrices.

**CO3:** Apply key results such as Cayley–Hamilton theorem, minimal polynomial, invariant subspaces, T-conductors, and T-annihilators in matrix and linear operator problems.

**CO4:** Determine and characterize diagonalizability and triangulability using minimal polynomials, multiplicities, and projections.

**CO5:** Understand advanced matrix structures including Jordan canonical form, rational canonical form, nilpotent operators, invariant direct sums, and quadratic forms.

**Books Recommended**


1. Vivek Sahai and Vikas Bist, *Linear Algebra*, alpha Science, 2001.
2. T. S. Blyth and Robertson, *Further Linear Algebra*, Springer, 2013.
3. K. Hofmann and R. Kunze, *Linear Algebra*, Prentice Hall of India, New Delhi, 1972.
4. D. S. Dummit and R. M. Foote, *Abstract Algebra*, John Wiley & Sons, N.Y., 2003.
5. N. Jacobson, *Basic Algebra*, Vol. 1, Hindustan Publishing Co., New Delhi, 1984.

# PG MATHEMATICS (SEMESTER-IX)

## OPERATIONS RESEARCH-II

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** IX |
| **Subject:** MATHEMATICS | | |
| **Course Code:** ME0103T | **Course Title:** OPERATIONS RESEARCH-II | |
| **Credits:** 4+0 | Core Compulsory / Elective | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |
| **Course Objectives:** The aim of this course is to teach the student the application of various numerical technique for variety of problems occurring in daily life. | | |

| Unit | Topics |
|---|---|
| | **OPERATIONS RESEARCH-II** |
| I | Game Theory- Two-Person zero-sum games, Games with mixed stategies, Graphical solution, solution by linear programming. |
| II | Sequencing problem- Basic terms used in sequencing, Processing n jobs through to machine, Processing n jobs through k machine, Processing 2 jobs through k machine, Problem of Replacement, Individuals and Group replacement policies. |
| III | Network analysis- Construction of a network diagram, PERT and CPM, Time estimates in PERT, Project Crashing. |
| IV | Non-Linear Programming- One and multi variable unconstrained optimization, Kuhn Tucker, Condition for constrained optimization, Quadratic Programming, Separable Programming, convex optimization, gradient descent, stochastic gradient descent. |

**Course Learning Outcomes:** After successful completion of this course student will be able

**CO1:** to know the concept of game theory and methods of finding suitable solution.

**CO2:** to know the method for solving extremal problems whose objective functions/constraints are non-linear.

**CO3:** to take multistage problems.

**CO4:** to know the methodology for solving networking problems.

**Books Recommended:**


1. S.D. Sharma, *Operations Research*, Kedar Nath Ram Nath & Company.
2. S.S. Rao, *Optimization Theory and Applications*, Wiley Eastern Ltd., New Delhi.
3. J.K. Sharma, *Operations Research: Theory and Applications*, Macmillan India Ltd.
4. H.A. Taha, *Operations Research: An Introduction*, Macmillan Publishing Co., Inc., New York.
5. Kanti Swarup, P.K. Gupta, Man Mohan, *Operations Research*, Sultan Chand & Sons, New Delhi.
6. B.S. Goel, S.K. Mittal, *Operations Research*, Pragati Prakashan, Meerut.
7. P.K. Gupta, D.S. Hira, *Operations Research: An Introduction*, S. Chand & Company Ltd., New Delhi.

## PG MATHEMATICS (SEMESTER-IX)

### NON-LINEAR ANALYSIS

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** IX |
| **Subject:** MATHEMATICS | | |
| **Course Code:** ME0104T | **Course Title:** NON LINEAR ANALYSIS | |
| **Credits:** 4+0 | Core Compulsory / Elective | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives**

1. To introduce the fundamentals of metric fixed point theory, including Banach spaces, convexity properties, Lipschitz and contraction mappings, and Banach's contraction principle.
2. To study fixed point results for nonexpansive, asymptotically nonexpansive, and quasi-nonexpansive mappings in Banach and Hilbert spaces.
3. To develop understanding of classical fixed point theorems such as Brouwer's and Schauder's, along with concepts like measure of non-compactness, condensing maps, and Sadovskii's theorem.
4. To provide knowledge of iterative methods and convergence techniques including Mann and Ishikawa iterations and their stability for nonlinear operator equations.

| Unit | Topics |
|---|---|
| | **NONLINEAR ANALYSIS** |
| I | Background of Metrical fixed point theory, Fixed Points, Uniformly convex, strictly convex and reflexive Banach spaces, Lipschitzian and contraction mapping, Banach's contraction principle, Application to Volterra and Fredholm integral equations. |
| II | Nonexpansive, asymptotically nonexpansive and quasi-nonexpansive mappings and Fixed Points, Fixed point theorems for nonexpansive mappings, Nonexpansive operators in Banach spaces satisfying Opial's conditions, The demiclosedness principle. |
| III | Brouwer's fixed point theorem, Schauder's fixed point theorem, Measure of Non- Compactness, Condensing map, Fixed points for condensing maps, Strict convexity, Uniform convexity, The modulus of convexity and normal structure, Smoothness, retraction map, Sadovskii's fixed point theorem, Introduction of Set-valued mappings, Set-valued contraction map. |
| IV | Fixed point iteration procedures, The Mann Iteration, Lipschitzian and Pseudo contractive operators in Hilbert spaces, Strongly pseudo contractive operators in Banach spaces, The Ishikawa iteration, Stability of fixed point iteration procedures. Iterative solution of Nonlinear operator equations in arbitrary and smooth Banach spaces, Nonlinear m-accretive operator, Equations in reflexive Banach spaces. |

**Course Learning Outcomes (COs)**

**CO1:** Understand the basic concepts of metric fixed point theory, including Banach spaces, convexity properties, Lipschitz and contraction mappings, and Banach's contraction principle.

**CO2:** Analyze fixed point results for nonexpansive, asymptotically nonexpansive, and quasi-nonexpansive mappings in Banach and Hilbert spaces.

**CO3:** Apply classical fixed point theorems such as Brouwer's, Schauder's, and Sadovskii's theorem along with concepts like measure of non-compactness and condensing maps.

**CO4:** Use iterative methods such as Mann and Ishikawa iterations to study convergence and stability of fixed point procedures in nonlinear operator equations.

**Books Recommended**


1. V. Berinde, *Iterative Approximation of Fixed Points*, Lecture Notes in Mathematics, No. 1912, Springer, 2007.
2. M. A. Khamsi and W. A. Kirk, *An Introduction to Metric Spaces and Fixed Point Theory*, John Wiley & Sons, New York, 2001.
3. Sankatha P. Singh, B. Watson and P. Srivastava, *Fixed Point Theory and Best Approximation: The KKM-map Principle*, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1997.
4. V. I. Istratescu, *Fixed Point Theory: An Introduction*, D. Reidel Publishing Co., 1981.
5. K. Goebel and W. A. Kirk, *Topics in Metric Fixed Point Theory*, Cambridge University Press, 1990.
6. Ravi P. Agarwal, Donal O'Regan, and D. R. Sahu, *Fixed Point Theory for Lipschitzian-type Mappings with Applications*, Springer, 2009.

## PG MATHEMATICS (SEMESTER-IX)

### NUMBER THEORY AND CRYPTOGRAPHY

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** IX |
| **Subject:** MATHEMATICS | | |
| **Course Code:** ME0105T | **Course Title:** NUMBER THEORY AND CRYPTOGRAPHY | |
| **Credits:** 4+0 | Core Compulsory / Elective | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives**

1. To introduce the basic concepts of divisibility theory, including gcd, lcm, Euclidean algorithm, and fundamental properties of integers.
2. To develop understanding of congruences, residue systems, and classical results such as Fermat's and Wilson's theorems along with their applications.
3. To provide knowledge of cryptography and classical encryption techniques, including substitution and transposition ciphers.
4. To study important number theoretic functions and advanced topics such as Euler's phi function, Möbius function, quadratic residues, and special number sequences.

| Unit | Topics |
|---|---|
| | **NUMBER THEORY AND CRYPTOGRAPHY** |
| I | Divisibility: Some basic terms and properties, Division algorithm, Common divisor, Greatest common divisor (gcd), Theorems on gcd, Euclid's lemma, relatively prime, Euclidian Algorithm, least common multiple (lcm), Theorems on lcm, Fundamental theorem of arithmetic, Euclid's theorem, Linear Diophantine Equation $a\,x + b\,y = c$ and its solutions. |
| II | Congruences: Basic properties and theorems of congruences, Residue and complete residue system, Reduced residue system, Fermat's theorem, Wilson theorem, Converse of Wilson theorem, Linear Congruences, Chinese remainder theorem, Method of solution of congruences, Binary and Decimal Representation of Integers. |
| III | Cryptography: Introduction of cryptography, Block Diagram of cryptography, some simple cryptosystems, additive cipher, shift cipher, caeser cipher, affine cipher, auto key cipher, play fair cipher, hill cipher or enciphering matrices, vigenere cipher, vernam cipher, rail fence cipher, simple columnar cipher, simple columnar with multiple rounds cipher. |
| IV | Arithmetic functions or Number-theoretic functions: The function $\boldsymbol{\tau}$ and $\boldsymbol{\sigma}$, Multiplicative function, Euler's phi-function, Euler's theorem, Moebius $\boldsymbol{\mu}$-function, Moebius inversion formula, Greatest integer function. Quadratic congruence: Quadratic congruence, Quadratic residues, Euler's criterion. Perfect number, Fermat number, Fibonacci sequence and numbers. |

**Course Learning Outcomes (COs)**

**CO1:** Apply the concepts of divisibility, including gcd, lcm, Euclidean algorithm, and linear Diophantine equations to solve mathematical problems.

**CO2:** Analyze and solve problems based on congruences, residue systems, Fermat's theorem, Wilson's theorem, and the Chinese Remainder Theorem.

**CO3:** Demonstrate understanding of classical cryptographic techniques such as Caesar, affine, Vigenère, Hill, Playfair, and transposition ciphers.

**CO4:** Evaluate and apply arithmetic functions and advanced number theory concepts including Euler's phi function, Möbius function, quadratic residues, and related theorems.

**Books Recommended**


1. Niven and Zuckerman, *An Introduction to the Theory of Numbers*, Wiley Eastern Ltd.
2. Ireland & Rosen, *A Classical Introduction to Modern Number Theory*, Springer.
3. Tom Apostol, *Introduction to Analytic Number Theory*, Narosa Publications, New Delhi.
4. Delfs, H., Knebl, H., *Introduction to Cryptography*, Springer.
5. Koblitz, N., *Algebraic Aspects of Cryptography*, Springer.
6. Serre, J.P., *A Course in Arithmetic*, Springer.
7. Cassels, J.W.S., Frolich, A., *Algebraic Number Theory*, Cambridge.

# PG MATHEMATICS (SEMESTER-IX)

## DIFFERENTIAL GEOMETRY

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** IX |
| **Subject:** MATHEMATICS | | |
| **Course Code:** ME0106T | **Course Title:** DIFFERENTIAL GEOMETRY | |
| **Credits:** 4+0 | Core Compulsory / Elective | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives:** The aim of this course is to introduce

1. introduce the concepts of binormal, osculating plane and Serrete-Frenet formula,
2. study of local theory of surfaces,
3. study of global theory of surfaces and fundamental equations of surface theory.

| Unit | Topics |
|---|---|
| | **DIFFERENTIAL GEOMETRY** |
| I | Tensor Algebra: Contravariant and covariant vector. Tensor product of vector spaces, tensor, contravariant, covariant and mixed tensor of second order. Tensor of type (r, s), tensor product of tensors. Symmetric and skew symmetric tensors, contraction. Definition and examples of differentiable manifold, Differentiable functions, Differentiable curves. |
| II | Curves in $R^2$ and $R^3$: Basic Definitions and Examples. Arc Length. Tangent and osculating plane, Principal normal and binormal, Curvature and torsion, The Frenet-Serret Apparatus. The Fundamental Existence and Uniqueness Theorem for Curves. |
| III | Local theory of Surfaces: Definition of a surface, Nature of points on a surface, Representation of a surface, Curves on surfaces, Tangent plane and surface normal, The general surfaces of revolution, Helicoids, Metric on a surface—The first fundamental form, Direction coefficients on a surface, Families of curves , Orthogonal trajectories. |
| IV | Global Theory of Surfaces: Normal Curvature, The second fundamental Form, Meusnier Theory, classification of points on a surface, Principal curvatures, Mean Curvature and Gaussian Curvature, Umbillic points, Lines of Curvature and Dupin's Theorem. Minimal Surfaces, Fundamental Equation of Surface Theory, Gauss's Equations, weingarten equations, Mainardi-Codazzi equations, Parallel surfaces. |

**Course Learning Outcomes:** After studying this course the student will be able to

CO1: to determine and calculate curvature of curves in different coordinate systems and existence, uniqueness of curves.

CO2: know the Local theory of surfaces.

CO3: know global theory of surfaces

CO4: know some fundamental equations of surface theory.

**Books Recommended:**


1. Christian Bär, *Elementary Differential Geometry*, Cambridge University Press, 2010.
2. D. Somasundaram, *Differential Geometry: A First Course*, Alpha Science International Ltd., 2005.
3. Pressley, *Elementary Differential Geometry*, Springer, 2010.
4. O'Neill, *Elementary Differential Geometry*, Elsevier, 2006.
5. R. S. Mishra, *A Course in Tensors with Applications to Riemannian Geometry*, Pothishala, Allahabad, 1965.
6. Y. Matsushima, *Differentiable Manifolds*, Marcel Dekker, 1972.
7. B. B. Sinha, *An Introduction to Modern Differential Geometry*, Kalyani Prakashan, New Delhi, 1982.
8. Y. Talpiert, *Differential Geometry with Applications to Mechanics and Physics*, Marcel Dekker Inc., 2001.
9. N. J. Hicks, *Notes on Differential Geometry*, D. Van Nostrand Inc., 1965.
10. U. C. De, A. A. Shaaikh, *Differential Geometry of Manifolds*, Narosa Publishing House, New Delhi, 2007.
11. K. S. Amur, D. J. Shetty, C. S. Bagewadi, *An Introduction to Differential Geometry*, Narosa Publishing House, New Delhi, 2010.
12. S. Shahshahani, *An Introductory Course on Differentiable Manifolds*, Dover Publication Inc., New York, 2016.

# PG MATHEMATICS (SEMESTER-IX)

## DISSERTATION / RESEARCH PROJECT

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** IX |
| **Subject:** MATHEMATICS | | |
| **Course Code:** MP0107R | **Course Title:** DISSERTATION/ RESEARCH PROJECT | |
| **Credits:** 0+4 | Core Compulsory | |
| **Max. Marks:** 100 | **Min. Passing Marks:** As per University CBCS Norm | |

**Course Objectives**

1. To develop basic research skills such as literature review, problem understanding, analysis, and structured presentation under the guidance of a supervisor.
2. To improve academic writing and communication skills through preparation of a typed dissertation and PowerPoint presentation.

### DISSERTATION/ RESEARCH PROJECT

Candidate/Students should write a dissertation/research project on the specific topic based on Mathematical sciences. The students have been allotted a supervisor in this dissertation/research project on their topic, given by the concern faculty. The dissertation/research project should be typed in LATEX/ MS-WORD and its presentation on Power Point / Beamer.

**Course Learning Outcomes**

**CO1:** Students will be able to conduct literature review and identify research problems in Mathematical Sciences.

**CO2:** Students will be able to analyze mathematical problems and present their findings in a systematic and scientific manner.

**CO3:** Students will be able to prepare a dissertation/research report using LaTeX/MS-Word with proper academic formatting.

**CO4:** Students will be able to effectively communicate research work through PowerPoint/Beamer presentations and technical discussions.

**Suggested Evaluation Methods (Max. Marks: 100)**

The project work shall be evaluated internally by the concerned department/subject teacher based on the quality of the research work, presentation, analysis, and understanding of the topic.

**Note:** A soft copy of the dissertation/research project must be submitted to the concerned department/subject teacher. There is no requirement to submit a hard copy of the dissertation/research project during this semester.

# PG MATHEMATICS (SEMESTER-X)

## FUNCTIONAL ANALYSIS

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** X |
| **Subject:** MATHEMATICS | | |
| **Course Code:** MC0201T | **Course Title:** FUNCTIONAL ANALYSIS | |
| **Credits:** 4+0 | Core Compulsory | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives:** The main objectives of this course is to

1. introduce normed linear spaces, Banach spaces, and their basic properties along with important examples.
2. study fundamental inequalities such as Cauchy–Schwarz, Hölder, and Minkowski inequalities and convergence concepts in normed spaces.
3. develop understanding of bounded linear operators, dual spaces, Hahn–Banach theorem, and its applications.
4. study major results in functional analysis including open mapping theorem, closed graph theorem, Baire category theorem, and Hilbert space theory.

| Unit | Topics |
|---|---|
| | **FUNCTIONAL ANALYSIS** |
| I | Normed linear spaces, Examples of normed linear spaces and its topological properties, Cauchy's inequality, Hölder's and Minkowski's inequality, Convergence in normed linear spaces, Cauchy sequence, Banach space, Examples of Banach space, Quotient space of normed linear space, Equivalent norms, Riesz lemma. |
| II | Continuous linear transformation Bounded linear transformations, Norm of bounded linear transformation, Space of bounded linear transformations. Conjugate space (dual space), Functional, Hahn-Banach theorem for real and complex normed linear spaces, Applications of Hahn- Banach theorem, The natural embedding. |
| III | Open mapping theorem, Projection of Banach space, Closed graph theorem, Baire category theorem, Uniform boundedness principle. Inner product spaces, Hilbert spaces with examples, Cauchy-Schwarz's inequality. |
| IV | Orthogonal complement, Orthonormal set and its existence, Bessel's inequality, Complete orthonormal sets and its characterization. Continuous linear functional on Hilbert space, Riesz representation theorem, Reflexivity of Hilbert space. Weak and strong convergence. |

**Course Learning Outcomes:** After the completion of the course, the student shall be able to

**CO1:** Know basics of Banach space as a part of functional analysis.

**CO2:** Determine the significance of functional analysis modern applied and computational mathematics.

**CO3:** Understand the application of Hilbert spaces in Mathematics and Physics typically as infinite dimensional function space.

**CO4:** Apply Hilbert spaces in solving partial differential equations and in studying Fourier analysis, etc.

**Books Recommended:**


1. G. F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw Hill, 1963.
2. S. Ponnusamy, *Foundations of Functional Analysis*, Narosa Publishing House, New Delhi, 2002.
3. G. Bachman, L. Narici, *Functional Analysis*, Academic Press, 1966.
4. A. E. Taylor, *Introduction to Functional Analysis*, John Wiley, 1958.
5. N. Dunford, J. T. Schwartz, *Linear Operators, Part-I*, Interscience, 1958.
6. R. E. Edwards, *Functional Analysis*, Holt Rinehart and Winston, 1965.
7. C. Gofman, G. Pedrick, *First Course in Functional Analysis*, Prentice-Hall of India, 1987.
8. R. Bhatia, *Notes on Functional Analysis*, Hindustan Book Agency, India, 2009.
9. E. Kreyszig, *Introductory Functional Analysis with Applications*, John Wiley & Sons, India, 2006.
10. M. Schechter, *Principles of Functional Analysis*, Second Edition, AMS, 2001.

# PG MATHEMATICS (SEMESTER-X)

## NORMED LINEAR SPACE AND THEORY OF INTEGRATION

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** X |
| **Subject:** MATHEMATICS | | |
| **Course Code:** ME0202T | **Course Title:** NORMED LINEAR SPACE AND THEORY OF INTEGRATION | |
| **Credits:** 4+0 | Core Compulsory / Elective | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives:** The purpose of this course is to

1. introduce LpL^pLp-spaces, convex functions, and key inequalities such as Hölder's, Minkowski's, and Jensen's inequalities.
2. study modes of convergence including convergence in measure and almost uniform convergence, and their completeness properties.
3. understand signed measures, Hahn and Jordan decomposition, Radon–Nikodym theorem, and Lebesgue decomposition.
4. study product measures, Tonelli's and Fubini's theorems, and representation theorems including Riesz–Markov theorem and integration on locally compact spaces.

| Unit | Topics |
|---|---|
| | **NORMED LINEAR SPACE AND THEORY OF INTEGRATION** |
| I | The $L^p$-space, Convex functions, Jensen's inequality, Holder's and Minkowski's inequalities, Completeness of Convergence in measure, Almost uniform convergence. |
| II | Signed measure, Hahn and Jordan decomposition theorems, Absolutely continuous and singular measures, Radon Nikodym theorem, Labesgue decomposition, Riesz representation theorem, Extension theorem (carathedory). |
| III | Product measures, Tonelli's theorem, Fubini's theorem, Baire sets, Baire measure, Continuous functions with compact support, Lebesgue-Stieltjes Integral. |
| IV | Regularity of measures on locally compact spaces, Integration of continuous functions with compact support, Reisz-Markoff theorem. |

**Course Learning Outcomes:** After studying this course the student will be able to

**CO1:** understand signed measures and complex measures, ability to use Hahn decomposition, Jordan decomposition, Radon-Nikodym theorem and recognize singularity of measures.

**CO2:** verify conditions under which a measure defined on a semi-algebra or algebra is extendable to a sigma-algebra and to get the extended measure, and to prove the uniqueness up to P multiplication by a scalar of Lebesgue measure in n as a translation invariant Borel measure.

**CO3:** learn and apply Riesz representation theorem for a bounded linear functional on spaces, understand product measure and the results of Fubini and Tonelli.

**CO4:** to understand the concepts of Baire sets, Baire measures, regularity of measures on locally compact spaces, Riesz-Markov representation theorem related to the representation of a bounded linear functional on the space of continuous functions.

**Books Recommended:**


1. C. D. Aliprantis, O. Burkinshaw, *Principles of Real Analysis*, Academic Press, Indian Reprint, 2011.
2. A. K. Berberian, *Measure and Integration*, AMS Chelsea Publications, 2011.
3. P. R. Halmos, *Measure Theory*, Springer, 2014.
4. M. E. Taylor, *Measure Theory and Integration*, American Mathematical Society, 2006.
5. H. L. Royden, P. M. Fitzpatrick, *Real Analysis*, Fourth Edition, Pearson, 2015.

# PG MATHEMATICS (SEMESTER-X)

## MODULE THEORY

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** X |
| **Subject:** MATHEMATICS | | |
| **Course Code:** ME0203T | **Course Title:** MODULE THEORY | |
| **Credits:** 4+0 | Core Compulsory / Elective | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives:** The main objectives of this course is to

1. introduce modules over rings, module homomorphisms, submodules, quotient modules, and fundamental isomorphism theorems.
2. study exact sequences, direct sums, products, free modules, and homological properties of modules.
3. develop understanding of projective modules, injective modules, divisible groups, and Baer's characterization.
4. study Artinian and Noetherian modules and rings, Hilbert basis theorem, modules over PID's, and semi-simple modules.

| Unit | Topics |
|---|---|
| | **MODULE THEORY** |
| I | Modules over a ring, Endomorphism ring of an abelian group, R-Module structure on an abelian group M as a ring homomorphism from R to $End_Z(M)$, submodules, Direct summands, Annihilators, Homomorphism, Correspondence theorem, Isomorphism theorems. |
| II | $Hom_R(M, N)$ as an abelian group and $Hom_R(M, M)$ as a ring, Exact sequences, Five lemma, Products, coproducts and their universal property, External and internal direct sums. Free modules, Homomorphism extension property, Equivalent characterization as a direct sum of copies of the underlying ring. |
| III | Split exact sequences and their characterizations, Left exactness of Hom sequences and counter-examples for non-right exactness, Projective modules, Injective modules, Baer's characterization, Divisible groups, Examples of injective modules, Existence of enough injectives. |
| IV | Artinian and Noetherian modules and rings, Equivalent characterizations, Submodules and factors of artinian and noetherian modules, Hilbert basis theorem, Modules over PID's, Semi-simple modules. |

**Course Learning Outcomes:** After studying this course the student will be able to

**CO1:** identify and construct example of modules, and apply homomorphism theorems on the same.

**CO2:** distinguish between projective, injective, free, and semi simple modules.

**CO3:** to understand the chain conditions on modules.

**CO4:** to characterize finitely generated modules over PID.

**Books Recommended:**


1. M. F. Atiyah, I. G. MacDonald, *Introduction to Commutative Algebra*, CRC Press, Taylor & Francis, 2018.
2. P. M. Cohn, *Basic Algebra: Groups, Rings and Fields*, Springer, 2005.
3. D. S. Dummit, R. M. Foote, *Abstract Algebra*, Third Edition, Wiley India Pvt. Ltd., 2011.
4. N. Jacobson, *Basic Algebra, Volumes I & II*, Second Edition, Dover Publications, 2009.
5. F. W. Anderson, K. R. Fuller, *Rings and Categories of Modules*, Springer-Verlag.
6. J. S. Golan, *Modules and Structures of Rings*, Marcel Dekker Inc.
7. N. S. Gopalakrishnan, *University Algebra*, Wiley Eastern, New Delhi, 1986.
8. I. A. Adamson, *An Introduction to Field Theory*, Oliver and Boyd, Edinburgh, 1964.
9. S. Lang, *Algebra*, Addison Wesley.
10. V. Sahai, V. Bist, *Algebra*, Fourth Edition, Narosa.
11. I. B. S. Passi, I. S. Luther, *Algebra, Volume 3: Modules*, Narosa.
12. H. K. Pathak, *Abstract Algebra*, Shiksha Sahitya Prakashan.

# PG MATHEMATICS (SEMESTER-X)

## DISCRETE MATHEMATICS

| **Class:** PG | **Year:** | **Semester:** X |
|---|---|---|
| **Subject:** MATHEMATICS | | |
| **Course Code:** ME0204T | **Course Title:** DISCRETE MATHEMATICS | |
| **Credits:** 4+0 | Core Compulsory / Elective | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives:** The course objective is to

1. introduce the fundamental concepts of lattices, distributive lattices, complemented lattices, and Boolean algebras.
2. study Boolean identities, canonical forms, minimization of Boolean functions, and applications of Boolean algebra in switching theory.
3. develop understanding of graph theoretic concepts including paths, cycles, trees, planar graphs, and graph connectivity.
4. study spanning trees, matrix representation of graphs, Eulerian graphs, directed graphs, weighted graphs, and tree traversals.

| Unit | Topics |
|---|---|
| | **DISCRETE MATHEMATICS** |
| I | **Lattices-** Lattices as partially ordered sets, their properties, Lattices as Algebraic system, Sub-lattices, direct product and Homomorphisms, complete, complemented and Distributive Lattices. |
| II | **Boolean Algebras-** Boolean Algebras as Lattices, Various Boolean Identities, switching algebra example, Sub-algebras, Direct products and Homomorphisms, Join-irreducible elements, Atoms and Minterms, Boolean forms and their equivalence, Minterm Boolean forms, sum of products, Canonical Forms, Minimization of Boolean Functions, Applications of Boolean Algebra to switching theory, the Karnaugh Map Method. |
| III | **Graph Theory-** Definition of Graphs, Paths, Circuits, Cycles and Subgraphs, Induced Subgraphs, Degree of a vertex, Connectivity, Planar Graphs, trees, Euler's formula for connected planar graphs, complete and complete Bipartite Graphs, Kuratowski's theorem and its use. |
| IV | Spanning trees, matrix representation of graphs, Euler's theorem on the existence of Eulerian Paths and circuits, directed graphs, Indegree and Outdegree of vertex, Weighted undirected Graphs, directed trees, search Trees, Tree Traversals. |

**Course Learning Outcomes:** After successful completion of this course, student will be able

CO1: to have the knowledge of lattices and behaviour as an algebraic system.

CO2: to kanow new algebraic structure, Boolean algebra, its behaviour as Lattices and its application in circuit theory.

CO3: to know the notion of graph, some special graph and coloring.

CO4: to understand searching algorithms for a tree and some other algorithms, kruskal and warshall's algorithm.

**Books Recommended:**


1. John E. Hopcroft, Rajeev Motwani, Jeffrey D. Ullman, *Introduction to Automata Theory, Languages and Computation*, Pearson Education, 2000.
2. Elliott Mendelson, *Introduction to Mathematical Logic*, Chapman & Hall, 1997.
3. Arnold B. H., *Logic and Boolean Algebra*, Prentice Hall, 1962.
4. K. H. Rosen, *Discrete Mathematics and Its Applications*, MGH, 1999.
5. D. B. West, *Graph Theory*, Pearson Publications, 2002.
6. F. Harary, *Graph Theory*, Narosa Publishing House, New Delhi.
7. R. Garnier, J. Taylor, *Discrete Mathematics for New Technology*, IOP Publishing, 2002.
8. A. C. Yadav, *Elements of Graph Theory*, Golden Valley Publication.

# PG MATHEMATICS (SEMESTER-X)

## DIFFERENTIAL GEOMETRY OF MANIFOLDS

| | | |
|---|---|---|
| **Class:** PG | **Year:** FOURTH | **Semester:** X |
| **Subject:** MATHEMATICS | | |
| **Course Code:** ME0205T | **Course Title:** DIFFERENTIAL GEOMETRY OF MANIFOLDS | |
| **Credits:** 4+0 | Core Compulsory / Elective | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives:** The aim of this course is to introduce

1. introduce the concepts of Nijenhuis tensor,
2. study of Contravariant and covariant almost analytic vector field,
3. study of Affine Connection and Holomorphic Sectional Curvature,
4. study of different type manifolds.

| Unit | Topics |
|---|---|
| | **DIFFERENTIAL GEOMETRY OF MANIFOLD** |
| I | Almost Complex manifold, Nijenhuis tensor, Contravariant and covariant almost analytic vector field, Affine Connection, F-connection. |
| II | Almost Hermite manifolds, Curvature tensor, Linear Connections, Kahler manifolds, Holomorphic Sectional Curvature, Nearly Kahler Manifolds. |
| III | Curvature Identities, Constant Holomorphic sectional Curvature, Almost Kahler Manifolds. |
| IV | Almost contact metric Manifolds, Almost Grayan Manifolds, K-contact Riemannan Manifolds, Sasakian Manifolds, Cosymplectic Manifolds. |

**Course Learning Outcomes:** After successful completion of this course student will be able

CO1: to determine concepts of Nijenhuis tensor in different manifolds.
CO2: Know the Holomorphic Sectional Curvature
CO3: know K-contact Riemannian manifold.
CO4: know Curvature tensor.
CO5. improve their skills in different manifold and also give Employability in teaching and research.

**Books Recommended:**


1. R. S. Mishra, *Structures on a Differentiable Manifold and Their Applications*, Chandrama Prakashan, Allahabad.
2. Y. Matsushima, *Differentiable Manifolds*, Marcel Dekker, 1972.
3. B. B. Sinha, *An Introduction to Modern Differential Geometry*, Kalyani Prakashan, New Delhi, 1982.
4. N. J. Hicks, *Notes on Differential Geometry*, D. Van Nostrand, 1965.
5. U. C. De, A. A. Shaikh, *Differential Geometry of Manifolds*, Narosa Publishing House.

# PG MATHEMATICS (SEMESTER-X)

## MATHEMATICAL MODELING

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** X |
| **Subject:** MATHEMATICS | | |
| **Course Code:** ME0206T | **Course Title:** MATHEMATICAL MODELING | |
| **Credits:** 4+0 | Core Compulsory / Elective | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives:** The objective of this course is to

1. introduce the basic concepts, techniques, classifications, characteristics, and limitations of mathematical modeling.
2. develop mathematical models using ordinary differential equations for growth, decay, and dynamic systems.
3. study mathematical modeling through difference equations and their applications in economics, finance, and population dynamics.
4. understand linear programming models, transportation and assignment problems, and logistic models used in applied sciences.

| Unit | Topics |
|---|---|
| | **MATHEMATICAL MODELING** |
| I | Simple situations requiring mathematical modeling, techniques of mathematical modeling, Classifications, Characteristics and limitations of mathematical models, Some simple illustrations. |
| II | Mathematical modeling through differential equations, linear growth and decay models, Non linear growth and decay models, Mathematical modeling in dynamics through ordinary differential equations of first order. |
| III | Mathematical models through difference equations, some simple models, Basic theory of linear difference equations with constant coefficients, Mathematical modeling through difference equations in economic and finance, Mathematical modeling through difference equations in population dynamic. |
| IV | Mathematical modeling through linear programming, Linear programming models in Transporta tion and assignment, non age and age structured models, simple logistic models, physical basis of logistic model, Smith's model. |

**Course Learning Outcomes:** After the completion of the course, the student shall be able to

**CO1:** assess and articulate what type of modeling techniques is appropriate for a system.

**CO2:** construct mathematical models in real-world biological phenomenon.

**CO3:** predict the behavior of a system based on the analysis of its mathematical model.

**Books Recommended:**


1. J. N. Kapur, *Mathematical Modelling*, New Age International (P) Limited, New Delhi, 2007.
2. J. N. Kapur, *Mathematical Models in Biology and Medicine*, Affiliated East-West Press Pvt. Ltd., New Delhi, 1985.
3. J. Mazumdar, *An Introduction to Mathematical Physiology and Biology*, Cambridge University Press, 1999.
4. D. N. Burghes, *Mathematical Modeling in the Social, Management and Life Science*, Ellie Horwood and John Wiley.
5. F. Charlton, *Ordinary Differential and Difference Equations*, Van Nostrand.

# PG MATHEMATICS (SEMESTER-X)

## OPERATOR THEORY

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** X |
| **Subject:** MATHEMATICS | | |
| **Course Code:** ME0207T | **Course Title:** OPERATOR THEORY | |
| **Credits:** 4+0 | Core Compulsory / Elective | |
| **Max. Marks:** 25(Internal) + 75(External) | **Min. Passing Marks:** As per University CBCS Norm | |
| **Total No. of Lectures-Tutorials-Practical (in hours per week):** L-T-P: 4-0-0 | | |

**Course Objectives:** The aim of this course is to

1. introduce the fundamental concepts of real Banach spaces, real Hilbert spaces, and bounded linear operators.
2. study important classes of operators such as adjoint, self-adjoint, normal, unitary, projection, and compact operators on Hilbert spaces.
3. develop understanding of spectral theory, including spectrum, resolvent, spectral theorem, spectral radius, and spectral mapping theorem.
4. study Banach algebras, ideals, maximal ideals, radicals, and the Gelfand–Naimark theorem in complex commutative Banach algebras.

| Unit | Topics |
|---|---|
| | **OPERATOR THEORY** |
| I | Introduction to real Banach and real Hilbert spaces, Adjoint of an operator on a Hilbert space, Self-adjoint operators, Normal operators and Unitary operators on Hilbert spaces, Projections on a Hilbert space. |
| II | Compact operators, Spectral theory of linear operators in normed linear space, Spectral theory of linear operators in finite dimensional normed linear spaces, Spectral properties of bounded linear operators. |
| III | Determinant and the spectrum of an operator, Spectral theorem, Resolvent and its properties, Spectrum and its properties, Residual spectrum, Approximate spectrum, Analyticity of the resolvent operator, Use of complex analysis in spectral theory, Spectral radius and the spectral mapping theorem for polynomials. |
| IV | Banach algebras, Banach algebras with identity, Division algebra, Further properties of Banach algebra, Compactness of the spectrum, Ideals and maximal ideals of a complex commutative Banach algebra, radicals, Gelfand-Naimark theorem. |

**Course Learning Outcomes:** After studying this course the student will be able to

**CO1:** Understand the structure of real Banach spaces, real Hilbert spaces, and bounded linear operators.

**CO2:** Study adjoint, self-adjoint, normal, unitary, projection, and compact operators on Hilbert spaces.

**CO3:** Analyze spectral theory of bounded linear operators, including spectrum, resolvent, and spectral theorem.

**CO4:** Develop understanding of Banach algebras, ideals, radicals, and the Gelfand–Naimark theorem.

**Books Recommended:**


1. G. F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill, 1963.
2. Erwin Kreyszig, *Introductory Functional Analysis with Applications*, John Wiley and Sons.
3. George Bachman and Lawrence Narici, *Functional Analysis*, Academic Press, New York, 1966.
4. John B. Conway, *A Course in Operator Theory*, Springer.
5. N. Saran and S. L. Shukla, *Functional Analysis*, Pragati Prakashan, Meerut.
6. J. N. Sharma and A. R. Vasishtha, *Functional Analysis*, Krishna Prakashan Media (P) Ltd., 2015.

# MATHEMATICS (SEMESTER-X)
## DISSERTATION/ RESEARCH PROJECT

| | | |
|---|---|---|
| **Class:** PG | **Year:** | **Semester:** X |
| **Subject:** MATHEMATICS | | |
| **Course Code:** MP0208R | **Course Title:** DISSERTATION/ RESEARCH PROJECT | |
| **Credits:**0 +4 | Core Compulsory | |
| **Max. Marks:** 100 | **Min. Passing Marks:** As per University CBCS Norm | |

**Course prerequisites:**
To study this course, a student must have passed Mathematics as Major Subject in UG Third Year Programme.

**Course Objectives**

1. To develop basic research skills such as literature review, problem understanding, analysis, and structured presentation under the guidance of a supervisor.
2. To improve academic writing and communication skills through preparation of a typed dissertation and PowerPoint presentation.

## DISSERTATION/ RESEARCH PROJECT

Candidate/Students should write a dissertation/research project on the specific topic based on Mathematical sciences. The students have been allotted a supervisor in this dissertation/research project on their topic, given by the concern faculty. The dissertation/research project should be typed in LATEX/ MS-WORD and its presentation on Power Point / Beamer.

**Course Learning Outcomes**

**CO1:** Students will be able to conduct literature review and identify research problems in Mathematical Sciences.

**CO2:** Students will be able to analyze mathematical problems and present their findings in a systematic and scientific manner.

**CO3:** Students will be able to prepare a dissertation/research report using LaTeX/MS-Word with proper academic formatting.

**CO4:** Students will be able to effectively communicate research work through PowerPoint/Beamer presentations and technical discussions.

**Suggested Evaluation Methods (Max. Marks: 100)**

The Dissertation/Research Project shall be evaluated by an external examiner appointed by the University.

The Dissertation/Research Project may either be a continuation of the previous semester's Dissertation/Research Project or an independent study.

A soft copy as well as a hard copy of the Dissertation/Research Project must be submitted to the concerned department.

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