**To,**

The Principal Secretary,
Raj Bhavan, Bihar,
Patna

Sub:-**Regarding submission of proposed course uniform syllabus of Mathematics for 3rd to 8th Semester of 4 - Year undergraduate Course under CBCS System as per UGC Regulations.**

Ref.:- Letter No.-BSU (UGC) -02/2023- 1457/ GS(I) dated 14.09.2023

Sir,

In compliance with your letter no. BSU(UGC)-02/2023-1457/GS(I), dated-14.09.2023, we are submitting the proposed course syllabus of **Mathematics** for 3rd to 8th semester of the 4 - year under graduate course (CBCS) as per UGC regulations.

**Yours sincerely,**


1 **Prof. Shambhu Kr Mishra**
Professor & Head
Patliputra University, Patna
Email.-shambhumishra5@gmail.com
Mobile -9430284208

2 **Dr. S.B. Rai**
Associate Professor,
Patna University, Patna
Email.- drsbrai5@gmail.com
Mobile -9801819536

3 **Dr. Gurudayal Singh**
HOD, P.G. Dept. of Math,
V K S University, Ara
Email.-gdsingh01967@gmail.com
Mobile -9931943209

4 **Dr. Rafiqul Hasan**
Professor, P.G. Dept. of Math,
**(Additional)**
T M B University, Bhagalpur
Email.-variantresearchcenter@gmail.com
Mobile -8986975175

5 **Dr. Bijendra Kumar***
Ex-HOD, P.G. Dept. of Math,
**(Additional)**
T M B University, Bhagalpur
Email.-drbijendra.krbjp@gmail.com
Mobile -8709882839

6 **Dr. Ashok Kumar**
Professor & Head, P.G. Dept. of Math,
**(Additional)**
J P University, Chapra
Email.-ashokdavsiwan@gmail.com
Mobile -8709792787

7 **Dr. Abdul Halim**
Assistant Professor, H.S. College,
H.Kharagpur
**(Additional)**
M G R University, Munger
Email.-abdul.math91@gmail.com
Mobile -8637572578

8 **Dr. Anupam Kumar Singh**
Assistant Professor & Head, Dept. of Mathematics,
C.M. College, Darbhanga
**(Additional)**
L N M University, Darbhanga
Email.-anupam09.bhu@gmail.com
Mobile -9399873239

9 **Dr. Manoj Kumar Manoranjan**
Professor & Head
**(Additional)**
B N M University, Madhepura
Email.-manojmanoranjan.kumar@gmail.com
Mobile -9431889129

10 **Dr. Kumar Vishal**
Assistant Professor, P.G. Dept. of Math,
**(Additional)**
Magadh University, Bodh Gaya
Email.-kumarvishal.bhu@gmail.com
Mobile -8385095319

11 **Dr. Vipul Kumar Baranwal**
Assistant Professor & Head, Dept. of Mathematics,
D.C. College, Hajipur
**(Additional)**
B RA Bihar University, Muzaffarpur
Email.-vkbaranwal1@gmail.com
Mobile -8130545394

12 **Dr. Raj Kishore Singh***
Retd. Associate Professor,
K.C.T.C. College, Raxaul
**(Additional)**
B RA Bihar University, Muzaffarpur
Email.-rajkishore775@gmail.com
Mobile -9431637923

# Syllabus for Major Courses (Mathematics) Semester-III to VIII

# SEMESTER- III

## MJC-03: Real Analysis

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Understand many properties of the real line and learn to define sequence in terms of functions.
**CO2:** Recognize bounded, convergent, divergent, Cauchy and monotonic sequences.
**CO3:** Apply tests for convergence and absolute convergence of an infinite series of real numbers.

| MJC-03: Real Analysis<br>(5 credits)<br>Full Marks- 100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Dedekind theory of real numbers, Algebraic and order properties of R, Archimedean Property, Density Theorem, Completeness property of R, Bounded sets, Theorems on Suprema and Infima. | 10 |
| 2 | Neighbourhood of a point in R, Open and closed sets, Limit points and isolated points of a set, Bolzano-Weierstrass theorem for a set, Derived set, Clouser and Interior of a set. | 12 |
| 3 | Sequence and its convergence, Bounded sequence, Monotone sequences, Subsequences, Limit of a sequence, Limit Theorem, Bolzano-Weierstrass theorem for sequences, Limit superior and limit inferior for bounded sequence, Cauchy sequence, Cauchy's general principle of convergence. | 14 |
| 4 | Infinite series and their convergence, Cauchy Criterion, Tests for convergence: Comparison test, D'Alembert Ratio Test, Cauchy's root test, Rabbe's test, Logarithmic test,D'Morgan and Bertrand's test, Cauchy integral test, Cauchy condensation test, Gauss's test, Alternating series, Leibnitz test, Absolute and Conditional convergence. | 14 |
| | **TOTAL** | 50 |

**Book References:**


1. Bartle, Robert G., &Sherbert, Donald R. (2015). Introduction to Real Analysis (4th ed.). Wiley India Edition. New Delhi.
2. Ross, Kenneth A. (2013). Elementary Analysis: The theory of calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.
3. Malik, S. C. & Arora, Savita. (2021). Mathematical Analysis (6th ed.). New Age International Publishers, New Delhi
4. Jha,K.K. Advanced Course in Real Analysis and Higher Analysis. New Bharat Publishing House.

# SEMESTER- III
# MJC-04: Ordinary Differential Equations

## Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Understand the concept of ordinary differential equation.
**CO2:** Solve first order linear and non-linear differential equation and linear differential equations of higher order using various techniques.
**CO3:** Apply these techniques to solve and analyze various mathematical models.

| MJC-04: Ordinary Differential Equations<br>(4 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Formulation of Differential equations and its order and degree, General, Particular and Singular solutions of differential equations, variables separable, Equations reducible to variables separable, Homogeneous differential equations, Equations reducible to homogeneous form, Exact differential equations and equations reducible to the exact form, Linear differential equations and equations reducible to linear form, Bernoulli equation. | 10 |
| 2 | Differential equations of first order but not of first degree, Singular solutions, Clairaut's form, Orthogonal Trajectories of family of curves, Wronskian and its properties, Linear differential equation of order greater than one with constant coefficients, Cauchy- Euler Equation, Legendre's Linear Equation. | 10 |
| 3 | Second order linear differential equations with variable coefficients: Use of a known solution to find another, normal form, method of undetermined coefficient, variation of parameters, Total differential equation in three variables, Simultaneous differential equations. | 10 |
| 4 | Definition of Laplace transform, Existence Theorem, Formulas and Properties of Laplace transform, Laplace transform of special functions viz: Dirac's delta, Unit step, Periodic, Bessel, Error functions, Inverse Laplace transform, Formulas and Properties of inverse Laplace transform, Convolution theorem, Solution of ordinary differential equation using Laplace transform. | 10 |
| | **TOTAL** | 40 |

**Book References:**


1. Simmons, George F. (2016). Differential Equations with Applications and Historical Notes. Tata–McGraw Hill Publishing Company Limited, New Delhi.
2. Raisinghania, M.D. (2020). Ordinary and Partial Differential Equations (20th ed.). S. Chand Publication.
3. Bronson, R. &Coasta, Gabriel B. (2021). Schaum's Outline of Differential Equations (5th ed.). McGraw Hill.
4. Prasad, Lalji. (2019). Differential Equations. Paramount Publication.

# SEMESTER – IV

## MJC-05: Theory of Real Functions

### Course Outcomes

**After the completion of the course, the student will be able to understand:**

**CO1:** The concept of limit of a function.
**CO2:** The geometrical properties of continuous functions on closed intervals.
**CO3:** The applications of mean value theorem and Taylor's theorem.

| MJC-05: Theory of Real Functions (Theory: 5 credits) Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Limit of functions, Sequential criterion for limits, Divergence criteria, Limit theorems, One-sided limits, Infinite limits and limits at infinity. | 10 |
| 2 | Continuous functions, Sequential criterion for continuity and discontinuity, Algebra of continuous functions, Properties of continuous functions on closed intervals, Uniform continuity, Uniform continuity theorem. | 14 |
| 3 | Differentiability of a function, Algebra of differentiable functions, Increasing and Decreasing functions, Sign of derivatives, Chain rule, Darboux's theorem, Intermediate value theorem for derivatives, Rolle's theorem, Lagrange's and Cauchy's Mean value theorem and their applications. | 14 |
| 4 | Taylor's theorem with Lagrange's and Cauchy's remainder forms, Maclaurin's theorem, Application of Taylor's theorem in error estimation, Extreme values, Theorems related to extrema. | 12 |
| | **TOTAL** | 50 |

**Book References:**


1. Bartle, Robert G., & Sherbert, Donald R. (2015). Introduction to Real Analysis (4th ed.). Wiley India Edition. New Delhi.
2. Ross, Kenneth A. (2013). Elementary Analysis: The theory of calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.
3. Malik, S. C. & Arora, S. (2021). Mathematical Analysis (6th ed.), New Age International Publishers, New Delhi
4. Jha,K.K. Advanced Course in Real Analysis and Higher Analysis. New Bharat Publishing House.

## SEMESTER- IV

# MJC-06: Group Theory

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc.

**CO2:** Explain the significance of the notion of cosets, normal subgroups, and factor groups.

**CO3:** Understand Automorphism, Class Equation and Sylow's theorem.

| MJC-06 : Group Theory<br>(5 credits)<br>Full Marks: 100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Definition and examples of groups, Elementary properties of groups, Subgroups and examples of subgroups, Generator of a group, Cyclic group, Properties of cyclic groups. | 10 |
| 2 | Permutations Group, Even and odd permutations, Alternating Group, Cosets and its properties, Lagrange's theorem, Fermat's Little theorem, Euler's theorem, Normal subgroups, Quotient groups, Center of a group, Normalizer of an element, Normalizer of a subgroup. | 10 |
| 3 | Group homomorphisms, Kernel of a group homomorphism, Fundamental theorem of group homomorphism, Isomorphisms, Properties of Isomorphisms, First, Second and Third isomorphism theorems for groups, Cayley's theorem. | 10 |
| 4 | Automorphism, Inner automorphism, Group of Automorphisms, Group Automorphisms of finite and infinite cyclic groups, Commutator subgroup. | 08 |
| 5 | Conjugacy classes, Class equation, p-groups, Cauchy's theorem for finite abelian groups, Sylow's theorems. | 12 |
| | **TOTAL** | 50 |

**Book References:**


1. Gallian, Joseph. A. (2013). Contemporary Abstract Algebra (8th ed.). Cengage Learning India Private Limited, Delhi. Fourth impression, 2015.
2. Herstein I.N. (2003). Topics in Algebra (2nd ed.). John Wiley & Sons.
3. Khanna, Vijay K. & Bhambri, S. K. A Course in Abstract Algebra (5th ed.). Vikash Publishing House Private Limited, New Delhi.
4. Fraleigh, John B. (2002). A Course in Abstract Algebra (7th ed.). Pearson Education.

# SEMESTER- IV

## MJC-07: Partial Differential Equations

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Formulate, classify and transform partial differential equations into canonical form.
**CO2:** Solve linear and non-linear partial differential equations using various methods.
**CO3:** Solve some physical problems.

| MJC-07: Partial Differential Equations<br>(5 credits)<br>Full Marks- 100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Partial differential equations – Basic concepts and definitions, Formation of PDEs, Classification of First order PDEs, Lagrange's and Charpit's method for solving PDEs. | 14 |
| 2 | Homogeneous and non-homogeneous Partial differential equation of second and higher order with constant coefficients, Partial differential equations reducible to equations with constant coefficients. | 12 |
| 3 | Partial differential equations of second order with variable coefficients, Monge's Methods, Classification of second order linear equations as hyperbolic, parabolic or elliptic, Reduction of second order linear equations to canonical forms. | 10 |
| 4 | Fourier series in (c, c + 2π), Dirichlet's condition (without proof), Euler's formulae, Fourier series for even and odd functions, Fourier series of arbitrary interval (0, 2L) and (-L, L), Fourier Half range sine and cosine series, Method of Separation of variables, Solution of the Wave, Heat and Laplace equations and their applications. | 14 |
| | **TOTAL** | 50 |

**Book References:**


1. Sneddon, Ian N. (2006). Elements of Partial Differential Equations. Dover Publications. Indian Reprint.
2. Raisinghania, M. D. (2018).Advanced Differential Equations (19th ed.). S. Chand Publication.
3. Raisinghania, M.D. (2020). Ordinary and Partial Differential Equations (20th ed.). S. Chand Publication.
4. Amarnath T. An elementary course in Partial differential equations (2nd ed.). Narosa Publication.

## SEMESTER -V

## MJC-08: Ring Theory and Linear Algebra-I

### Course Outcomes

**After the completion of the course, the student will be able to understand:**

**CO1:** The fundamental concept of Rings, Fields, subrings, integral domains, ring homomorphisms and their properties.

**CO2:** The concept of linear independence of vectors over a field, the idea of a finite dimensional vector space, basis of a vector space and the dimension of a vector space.

**CO3:** Basic concepts of linear transformations, the Rank-Nullity Theorem, matrix of a linear transformation, algebra of transformations and the change of basis.

| **MJC-08 : Ring Theory and Linear Algebra-I (5 credits) Full Marks-100** | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Definition and examples of rings, Properties of rings, Definition and examples of Subrings, Zero divisors, Integral domains and its examples, Properties of integral domains, Division rings, fields, Characteristic of a ring, Ideals and its properties, Quotient rings. | 14 |
| 2 | Ring homomorphisms, Kernel of Ring homomorphisms, Properties of ring homomorphisms, Isomorphism theorems for Rings. | 10 |
| 3 | Vector spaces, Subspaces, Algebra of subspaces, Linear combination of vectors, Linear span, Linear independence, Basis and dimension, Dimension of subspaces, Quotient spaces. | 14 |
| 4 | Linear transformations, Null Spaces and Ranges, Matrix representation of a linear transformation, Rank-Nullity theorem, Algebra of linear transformation, Eigenvalues and Eigenvectors, Characteristic equation of a matrix and Cayley-Hamilton theorem. | 14 |
| 5 | Isomorphisms for vector spaces, Isomorphism theorems for vector spaces, Invertibility and Isomorphisms. | 8 |
| | **TOTAL** | 60 |

**Book References:**


1. Gallian, Joseph. A. (2013). Contemporary Abstract Algebra (8th ed.). Cengage Learning India Private Limited. Delhi. Fourth impression, 2015.
2. Herstein, I. N. (2006). Topics in Algebra (2nd ed.). Wiley Student Edition. India.
3. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2003). Linear Algebra (4th ed.). Prentice-Hall of India Pvt. Ltd. New Delhi.
4. Kumaresan, S. (2000). Linear Algebra: A Geometric Approach, Prentice Hall India Learning Private Limited, New title Edition.
5. Hoffman, Kenneth & Kunze, Ray Alden (1978). Linear Algebra (2nd ed.). Prentice-Hall of India Pvt. Limited. Delhi. Pearson Education India Reprint, 2015.

# SEMESTER – V

## MJC-09: Multivariate Calculus

### Course Outcomes

**After the completion of the course, the student will be able to understand:**

**CO1:** The conceptual variations when advancing in calculus from one variable to multivariable discussions.

**CO2:** Inter-relationship amongst the line integral, double and triple integral formulations.

**CO3:** Applications of multi variable calculus tools in physics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

| MJC-09 : Multivariate Calculus<br>(5 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Functions of several variables, Limits and continuity, Partial derivatives, Euler's theorem, Higher order partial derivatives, Total differential and differentiability, Schwarz and Young's theorem, Chain rule. | 12 |
| 2 | Directional derivatives, Gradient, Maximal and normal property of the gradient, Tangent planes and normal lines, Level curves and surfaces, Gradient and Tangents to Level curves, Extrema of functions of two variables, Critical points, Saddle points, Method of Lagrange multipliers. | 12 |
| 3 | Double integrals in Cartesian and polar co-ordinates, area and surface area, Triple integrals, Volume by triple integrals, triple integrals in cylindrical and spherical coordinates, Change of variables in double and triple integrals. | 14 |
| 4 | Line integrals, Applications of line integrals: Mass and Work, Fundamental theorem for line integrals, Definition of vector field, Conservative vector fields, Divergence and curl. | 12 |
| 5 | Green's theorem- Tangential and Normal form, Evaluation of line integrals using Green's theorem, Surface integrals, Stokes' theorem, The Gauss divergence theorem. | 10 |
| | **TOTAL** | 60 |

**Book References:**


1. Malik, S.C. & Arora, Savita (2017). Mathematical Analysis, New Age International Private Limited.
2. Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). Calculus (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011.
3. Marsden, J. E., Tromba, A., & Weinstein, A. (2004). Basic Multivariable Calculus. Springer (SIE). First Indian Reprint.
4. George B. Thomas, Joel Hass, Christopher Heil, Maurice D. Weir, Thomas' Calculus, 14e Paperback, Pearson Education.
5. Prasad Lalji, Advanced Calculus, Paramount Publications, Revised Edition (2015).

# SEMESTER – VI
# MJC-10: Complex Analysis

## Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Understand the significance of differentiability of complex functions leading to the understanding of Cauchy-Riemann equations.

**CO2:** Evaluate the contour integrals and understand the role of Cauchy-Goursat theorem and the Cauchy integral formula.

**CO3:** Expand some simple functions as their Taylor and Laurent series, get familiar with the linear transformation and Mobius transformation.

| **MJC-10: Complex Analysis (4 credits) Full Marks-100** | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Introduction to complex number and its geometrical interpretation, algebra of complex numbers, functions of complex variables, limit of a complex function, continuity and uniform continuity, differentiability, Analytic and regular functions, Cauchy-Riemann equation and it's applications. | 08 |
| 2 | Exponential function, logarithmic function, Branches and derivatives of logarithms, trigonometric and hyperbolic functions, derivatives of functions, Definite integrals of functions, Contours, Contour integrals with examples, Upper bounds for moduli of contour integrals. | 08 |
| 3 | Complex integration, Cauchy's theorem, Cauchy's Goursat theorem, primitives, Cauchy's integral formula, Cauchy's integral formula for the derivative of an analytic function, Morera's theorem, Poisson's integral formula for a circle, Cauchy's inequality, Liouville's Theorem and Fundamental theorem of Algebra. | 08 |
| 4 | Convergence of sequences and series, Taylor series with examples; Laurent series and its examples, Absolute and uniform convergence of power series, Uniqueness of series representations of power series. | 08 |
| 5 | Linear Transformation, Jacobian of a transformation, Elementary transformations: translation, rotation, magnification, inversion, Mobius transformation (bilinear transformation), Cross ratio, preservation of cross ratio under bilinear transformation, fixed point of a bilinear transformation. | 08 |
| | **TOTAL** | 40 |

**Book References:**


1. Brown, James Ward, & Churchill, R. V. (2014). Complex Variables and Applications (9th ed.). McGraw-Hill Education. New York.
2. S. Ponnusamy, (2011) Foundation of complex Analysis, Alpha Science International Ltd. UK.
3. Bak, Joseph & Newman, Donald J. (2010). Complex analysis (3rd ed.). Undergraduate Texts in Mathematics, Springer. New York.
4. Zills, Dennis G., & Shanahan, Patrick D. (2003). A First Course in Complex Analysis with Applications. Jones & Bartlett Publishers, Inc.
5. Mathews, John H., & Howell, Rusell W. (2012). Complex Analysis for Mathematics and Engineering (6th ed.). Jones & Bartlett Learning. Narosa, Delhi. Indian Edition.

# SEMESTER – VI

## MJC-11: Metric Space

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Understand the basic concepts of metric spaces;

**CO2:** Correlate these concepts to their counter parts in real analysis;

**CO3:** Understand the abstractness of the concepts such as open balls, closed balls, compactness, connectedness etc. beyond their geometrical imaginations.

| MJC-11: Metric Space<br>(5 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Definition and examples of metric spaces, notion of Open and closed ball, Neighborhood of a point, Open set, Interior point, Interior of a set, Limit point of a set, Derived set, Closed set, Closure of a set, Diameter of a set, Dense set, Subspaces. | 12 |
| 2 | Sequences in metric spaces, Cauchy sequences, Complete metric space, Cantor's intersection theorem, Baire's category theorem, Contraction mapping, Banach fixed point theorem. | 12 |
| 3 | Continuous mappings, Sequential criterion and other characterizations of continuity, Uniform continuity, Homeomorphism. | 10 |
| 4 | Connectedness, Connected subsets of R, Connectedness and continuous mappings. | 08 |
| 5 | Compactness, boundedness, Continuous functions on compact spaces. | 08 |
| | **TOTAL** | 50 |

**Book References:**


1. Kumaresan, S. (2014). Topology of Metric Spaces (2nd ed.). Narosa Publishing House. New Delhi.
2. Simmons, G. F. (2004). Introduction to Topology and Modern Analysis. Tata McGraw Hill. New Delhi.
3. E.T. Copson, (1968) Metric Spaces, Cambridge University Press
4. S. Shirali and H.L. Vasudeva, Metric Spaces, Springer.
5. P. K. Jain and K. Ahmad, Metric Spaces, Narosa Publishing House.

# SEMESTER – VI
## MJC-12: Riemann Integration and Series of Functions

### Course Outcomes

**After the completion of the course, the student will be able to understand:**

**CO1:** Some of the families and properties of Riemann integrable functions, and the applications of the fundamental theorems of integration.

**CO2:** Apply Beta and Gamma functions and their properties in finding improper integrals, area under a curve and surface of revolution.

**CO3:** The valid situations for the inter-changeability of differentiability and integrability with infinite sum, and approximation of transcendental functions in terms of power series.

| **MJC-12: Riemann Integration and Series of Functions (5 credits) Full Marks-100** | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Definition and existence of Riemann Integral of bounded functions,Darboux theorem,necessary and sufficient condition for R-Integrability, Riemann integrability of continuous functions, monotonic function and function having finite number of discontinuities, Riemann integral as the limit of a sum, fundamental theorem of integral calculus, Mean value theorems. | 14 |
| 2 | Improper integrals of Type-I, Type-II and mixed type, test for convergence of improper integral such as comparison test and μ-test, Convergence of Beta and Gamma functions and their properties. | 12 |
| 3 | Pointwise and uniform convergence of sequence of functions, Cauchy criterion for uniform convergence, theorems on boundedness, continuity, derivability and integrability of the limit function of a sequence of functions with uniform convergence. | 08 |
| 4 | Series of functions, Theorems on the continuity, integrability and derivability of the sum function of a uniformly convergence series of functions, Cauchy criterion for uniform convergence and Weierstrass M-Test. | 08 |
| 5 | Power series, radius of convergence, Cauchy Hadamard Theorem, Differentiation and integration of power series, Abel's Theorem, Weierstrass Approximation Theorem. | 08 |
| | **TOTAL** | 50 |

**Book References:**


1. Bartle, Robert G., & Sherbert, Donald R. (2015). Introduction to Real Analysis (4th ed.). Wiley India Edition. Delhi.
2. Ghorpade, Sudhir R. & Limaye, B. V. (2006). A Course in Calculus and Real Analysis. Undergraduate Texts in Mathematics, Springer (SIE). First Indian reprint.
3. Ross, Kenneth A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer.
4. Shanti Narayan, Elements of Real Analysis, S. Chand Publication.
5. S. Ponnusamy, Foundations of Mathematical Analysis, Birkhasuer.
6. K K Jha, Advanced Real Analysis.
7. S.K. Mapa, Introduction to Real Analysis, Sarat Book Distributor, Kolkata.

## SEMESTER – VII

## MJC-13: Ring Theory and Linear Algebra-II

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Appreciate the significance of factorization in rings and integral domains.
**CO2:** Compute the characteristic polynomial, eigenvalues, eigenvectors, and eigenspaces, as well as the geometric and the algebraic multiplicities of eigenvalues.
**CO3:** Compute inner products and determine orthogonality on vector spaces, including Gram-Schmidt orthogonalization to obtain orthonormal basis.

| MJC-13: Ring Theory and Linear Algebra-II<br>(5 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Field of quotients of an integral domain, Embedding of rings, Polynomial rings, The Division algorithm and consequences, The Remainder Theorem, The Factor Theorem, Irreducible Polynomials, Reducible polynomials, Primitive Polynomial, Gauss's Lemma, Irreducibility tests, Unique factorization domains. | 14 |
| 2 | Linear Functionals, Dual spaces, dual basis, Double dual, Annihilators, Transpose of a linear transformation and its matrix in the dual basis. | 12 |
| 3 | Eigenspaces of a linear operator, Diagonalization of Linear Operators, Invariant subspaces, The minimal polynomial for a linear operator. | 10 |
| 4 | Inner products and Norms, Orthonormal basis, Gram-Schmidt orthogonalization process, Orthogonal complements, Bessel's inequality. | 10 |
| 5 | The adjoint of a linear operator, Least squares approximation, Minimal solutions to systems of linear equations, Normal and Self-Adjoint Operators, Unitary and orthogonal operators | 14 |
| | **TOTAL** | 60 |

**Book References:**


1. Gallian, Joseph. A. (2019). Contemporary Abstract Algebra (9th ed.), Cengage Learning India Private Limited.
2. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2022). Linear Algebra (5th ed.), Pearson Education.
3. Herstein, I. N. (2006). Topics in Algebra (2nd ed.). Wiley Student Edition. India.
4. Hoffman, Kenneth M., & Kunze, Ray Alden (1978). Linear Algebra (2nd ed.). Prentice-Hall of India Pvt. Limited. Delhi. Pearson Education India Reprint, 2015.
5. Kumaresan, S. (2000). Linear Algebra: A Geometric Approach, Prentice Hall India Learning Private Limited, New title Edition

# SEMESTER – VII
# MJC-15: Numerical Methods

## Course Outcomes

**After the completion of the course, the student will be able to understand:**

**CO1:** Various numerical techniques to find the zeroes of nonlinear functions of single variable and solution of a system of linear equations up to a certain given level of precision.

**CO2:** Interpolation techniques to compute the values of functions for equal and unequal intervals.

**CO3:** Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

| **MJC-15: Numerical Methods (6 credits) Full Marks-100** | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Errors: Relative, Absolute, Round off, Truncation, Finding roots of Transcendental and Polynomial equations: Bisection method, Secant method, Regula-Falsi method, Newton-Raphson method, Fixed point iteration method, Rate of convergence. | 12 |
| 2 | Solution of system of linear algebraic equations: Partial pivoting, LU decomposition and its applications, Gaussian Elimination and Gauss Jordan methods, Gauss Jacobi method, Gauss Seidel method, SOR methods and their convergence analysis. | 12 |
| 3 | Finite differences, Interpolation, Newton's Forward and Backward interpolation, Stirling's Formula, Bessel formula, Newton's divided difference, Lagrange's Interpolation, Inverse Interpolation. | 12 |
| 4 | Numerical differentiation, Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's $1/3^{rd}$ rule, Simpsons $3/8^{th}$ rule, Gauss quadrature formula. | 12 |
| 5 | Solution of difference equation of the first order, General solution, Linear difference equation with constant co-efficient, Solution of ordinary differential equations one step method: Euler's and modified Euler's method, Picard's method, Runge-Kutta methods. | 12 |
| | **TOTAL** | 60 |

**Book References:**


1. S. S. Sastry, Introductory Methods of Numerical Analysis: Prentice-Hall of India, 5th edition, 2012.
2. S. R. K. Iyengar, R. K. Jain and M. K. Jain, Numerical Methods for Scientific and Engineering Computation: New Age International, 6th edition, 2012.
3. V. Rajaraman, Computer oriented Numerical Methods: Prentice-Hall of India, 3rd edition, 2004.
4. E. Balaguruswamy, Numerical Methods: Mcgraw Hill Education, 1st edition, 1999.
5. Bradie, Brian. (2006). A Friendly Introduction to Numerical Analysis. Pearson Education, India. Dorling Kindersley (India) Pvt. Ltd. Third impression 2011.

# SEMESTER – VIII

## MJC-16: Mathematical Finance

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Interest rates and its types.

**CO2:** Financial markets and derivatives including options and futures.

**CO3:** Pricing and hedging of options, interest rate swaps and no-Arbitrage pricing concept.

| MJC-16 : Mathematical Finance<br>(Theory: 4 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Interest rates, Types of rates, Measuring interest rates, Zero rates, Bond pricing, Forward rate, Duration, Convexity, Exchange traded markets and OTC markets. | 10 |
| 2 | Derivatives--Forward contracts, Futures contract, Options, Types of traders, Hedging, Speculation, Arbitrage, No Arbitrage principle, Short selling, Forward price for an investment asset. | 10 |
| 3 | Types of Options, Option positions, Underlying assets, Factors affecting option prices, Bounds on option prices, Put-call parity, Early exercise, Effect of dividends. | 10 |
| 4 | Binomial option pricing model, Risk neutral valuation (for European and American options on assets following binomial tree model), Lognormal property of stock prices, Distribution of rate of return, expected return. | 10 |
| | **TOTAL** | 40 |

**Book References:**


1. Hull, J. C., &Basu, S. (2010). Options, Futures and Other Derivatives (7th ed.). Pearson Education. New Delhi.
2. Luenberger, David G. (1998). Investment Science, Oxford University Press. Delhi.
3. Ross, Sheldon M. (2011). An elementary Introduction to Mathematical Finance (3rd ed.). Cambridge University Press. USA.

# Syllabus for Minor Courses (Mathematics) Semester-III to VIII

## SEMESTER- III

## MIC-03: Real Analysis

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Understand many properties of the real line and learn to define sequence in terms of functions.
**CO2:** Recognize bounded, convergent, divergent, Cauchy and monotonic sequences.
**CO3:** Apply tests for convergence and absolute convergence of an infinite series of real numbers.

| MIC-03: Real Analysis<br>(3 credits)<br>Full Marks- 100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Dedekind theory of real numbers, Algebraic and order properties of R, Archimedean Property, Density Theorem, Completeness property of R, Bounded sets, Theorems on Suprema and Infima. | 10 |
| 2 | Sequence and its convergence, Bounded sequence, Monotone sequences, Subsequences, Limit of a sequence, Limit Theorem, Bolzano-Weierstrass theorem for sequences, Cauchy sequence, Cauchy's general principle of convergence. | 10 |
| 3 | Infinite series and their convergence, Cauchy Criterion, Tests for convergence: Comparison test, D'Alembert Ratio Test, Cauchy's root test, Rabbe's test, Logarithmic test, Cauchy integral test, Gauss's test, Alternating series, Leibnitz test, Absolute and Conditional convergence. | 10 |
| | **TOTAL** | 30 |

**Book References:**


1. Bartle, Robert G., & Sherbert, Donald R. (2015). Introduction to Real Analysis (4th ed.). Wiley India Edition. New Delhi.
2. Ross, Kenneth A. (2013). Elementary Analysis: The theory of calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.
3. Malik, S. C. & Arora, Savita. (2021). Mathematical Analysis (6th ed.). New Age International Publishers, New Delhi.
4. Jha,K.K. Advanced Course in Real Analysis and Higher Analysis. New Bharat Publishing House.

## SEMESTER-IV

## MIC-04: Ordinary Differential Equations

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Understand the concept of ordinary differential equation.
**CO2:** Solve first order linear and non-linear differential equation and linear differential equations of higher order using various techniques.
**CO3:** Apply these techniques to solve and analyze various mathematical models.

| MIC-04: Ordinary Differential Equations<br>(3 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Formulation of Differential equations and its order and degree, General, Particular and Singular solutions of differential equations, variables separable, Equations reducible to variables separable, Homogeneous differential equations, Equations reducible to homogeneous form, Exact differential equations and equations reducible to the exact form, Linear differential equations and equations reducible to linear form, Bernoulli equation. | 10 |
| 2 | Differential equations of first order but not of first degree, Singular solutions, Clairaut's form, Linear differential equation of order greater than one with constant coefficients, Cauchy- Euler Equation, Legendre's Linear Equation. | 10 |
| 3 | Second order linear differential equations with variable coefficients: Use of a known solution to find another, normal form, method of undetermined coefficient, variation of parameters, Total differential equation in three variables, Simultaneous differential equations. | 10 |
| | **TOTAL** | 30 |

**Book References:**


1. Simmons, George F. (2016). Differential Equations with Applications and Historical Notes. Tata–McGraw Hill Publishing Company Limited, New Delhi.
2. Raisinghania, M.D. (2020). Ordinary and Partial Differential Equations (20th ed.). S. Chand Publication.
3. Bronson, R. &Coasta, Gabriel B. (2021). Schaum's Outline of Differential Equations (5th ed.). McGraw Hill.
4. Prasad, Lalji. (2019). Differential Equations. Paramount Publication.

## SEMESTER – V

## MIC-05: Theory of Real Functions

### Course Outcomes

**After the completion of the course, the student will be able to understand:**

**CO1:** The concept of limit of a function.
**CO2:** The geometrical properties of continuous functions on closed intervals.
**CO3:** The applications of mean value theorem.

| MIC-05: Theory of Real Functions<br>(3 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Limit of functions, Sequential criterion for limits, Divergence criteria, Limit theorems, One-sided limits, Infinite limits and limits at infinity. | 08 |
| 2 | Continuous functions, Sequential criterion for continuity and discontinuity, Algebra of continuous functions, Properties of continuous functions on closed intervals. | 10 |
| 3 | Differentiability of a function, Algebra of differentiable functions, Increasing and Decreasing functions, Sign of derivatives,Darboux's theorem, Intermediate value theorem for derivatives, Rolle's theorem, Lagrange's and Cauchy's Mean value theorem and their applications. | 12 |
| | **TOTAL** | 30 |

**Book References:**


1. Bartle, Robert G., & Sherbert, Donald R. (2015). Introduction to Real Analysis (4th ed.). Wiley India Edition. New Delhi.
2. Ross, Kenneth A. (2013). Elementary Analysis: The theory of calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.
3. Malik, S. C. & Arora, S. (2021). Mathematical Analysis (6th ed.), New Age International Publishers, New Delhi.
4. Jha,K.K. Advanced Course in Real Analysis and Higher Analysis. New Bharat Publishing House.

## SEMESTER- V

## MIC-06: Group Theory

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc.

**CO2:** Explain the significance of the notion of cosets, normal subgroups, and factor groups.

**CO3:** Understand the concept of group homomorphism and isomorphism.

| MIC-06: Group Theory<br>(3 credits)<br>Full Marks: 100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Definition and examples of groups, Elementary properties of groups, Subgroups and examples of subgroups, Generator of a group, Cyclic group, Properties of cyclic groups. | 10 |
| 2 | Permutations Group, Even and odd permutations, Alternating Group, Cosets and its properties, Lagrange's theorem, Fermat's Little theorem, Normal subgroups, Quotient groups, Center of a group, Normalizer of an element, Normalizer of a subgroup. | 10 |
| 3 | Group homomorphisms, Kernel of a group homomorphism, Fundamental theorem of group homomorphism, Isomorphisms, Properties of Isomorphisms, First, Second and Third isomorphism theorems for groups, Cayley's theorem. | 10 |
| | **TOTAL** | 30 |

**Book References:**


1. Gallian, Joseph. A. (2013). Contemporary Abstract Algebra (8th ed.). Cengage Learning India Private Limited, Delhi. Fourth impression, 2015.
2. Herstein I. N. (2003). Topics in Algebra (2nd ed.). John Wiley & Sons.
3. Khanna, Vijay K. & Bhambri, S. K. A Course in Abstract Algebra (5th ed.). Vikash Publishing House Private Limited, New Delhi.
4. Fraleigh, John B. (2002). A Course in Abstract Algebra (7th ed.). Pearson Education.

## SEMESTER- VI

## MIC-07: Partial Differential equation

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Formulate, classify and transform partial differential equations into canonical form.

**CO2:** Solve linear and non-linear partial differential equations using various methods; and apply these methods in solving some physical problems.

**CO3:** Apply Laplace transformation for solving PDEs.

| MIC-07: Partial Differential Equation<br>(3 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Introduction to PDEs, Order and Degree of a PDE, Classification of partial differential equations (PDEs), formation and solution of PDEs, derivation of PDEs by elimination of arbitrary functions. | 10 |
| 2 | Linear partial differential equation of first order, Lagrange's solution of linear equation, Solution of partial differential equations using Charpit's method, solution of equations of the form f(p,q)=0, f(z,p,q)=0, f(x,p)=f(y,q) and z=px+qy+f(p,q) using Charpit's method. | 10 |
| 3 | Laplace transforms and its application to partial differential equations. Inverse Laplace transformations and its properties, convolutions. | 10 |
| | **TOTAL** | 30 |

**Book References:**


1. Myint-U, Tyn& Debnath, Lokenath. (2007). Linear Partial Differential Equation for Scientists and Engineers (4th ed.). Springer, Third Indian Reprint, 2013.
2. Sneddon, I. N. (2006). Elements of Partial Differential Equations, Dover Publications. Indian Reprint.
3. M. D. Raisinghania, Ordinary and Partial Differential Equations, S. Chand Publication.
4. Peter J. Olver, Introduction to partial differential equations, Speringer
5. S.K. Pundir and R. Pundir, Advanced Partial Differential Equations (with boundary value problems), Pragati Prakashan.

## SEMESTER- VI

## MIC-08: Ring Theory and Linear Algebra

### Course Outcomes

**After the completion of the course, the student will be able to understand:**

**CO1:** The fundamental concept of Rings, subrings, ideals and the corresponding homomorphisms.

**CO2:** The concept of linear independence of vectors over a field, the idea of a finite dimensional vector space, basis of a vector space and the dimension of a vector space.

| MIC-08: Ring Theory and Linear Algebra<br>(3 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Definition and examples of rings, properties of rings, subrings, characteristics of a subring, Ideal, Ideal generated by a subset of a ring, quotient ring, operation on ideals, prime and maximal ideals. | 10 |
| 2 | Ring homomorphisms, properties of ring homomorphism, isomorphism theorems. | 10 |
| 3 | Definition of linear space, general properties of linear space, vector subspaces, linear combination of vectors, linear span. Linear dependence and independence of vectors, basis of a vector space, finite dimensional vector spaces. | 10 |
| | **TOTAL** | 30 |

**Book References:**


1. Gallian, Joseph. A. (2013). Contemporary Abstract Algebra (8th ed.). Cengage Learning India Private Limited. Delhi. Fourth impression, 2015.
2. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2003). Linear Algebra (4th ed.). Prentice-Hall of India Pvt. Ltd. New Delhi.
3. I.N. Herstein, Abstract Algebra, Prentice Hall, New Jersey.
4. Hoffman and Kunze, Linear Algebra.
5. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
6. Lalji Prasad, Linear Algebra, Paramount Publications.
7. S.K. Mapa, Higher Algebra (Abstract and Linear), Levant Books, Kolkata.

## SEMESTER- VII

## MIC-09: Multivariate Calculus

### Course Outcomes

**After the completion of the course, the student will be able to understand:**

**CO1:** The conceptual variations when advancing in calculus from one variable to multivariable discussions.

**CO2:** Inter-relationship amongst the line integral, double and triple integral formulations.

**CO3:** Applications of multi variable calculus tools in different disciplines.

| MIC-09 : Multivariate Calculus<br>(4 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Functions of several variables, Limits and continuity, Partial derivatives, Higher order partial derivatives, Euler's theorem on Homogeneous function | 10 |
| 2 | Double integrals in Cartesian and polar co-ordinates, Triple integrals, Change of variables in double and triple integrals. | 10 |
| 3 | Line integrals, Applications of line integrals: Mass and Work, Fundamental theorem for line integrals, Definition of vector field, Conservative vector fields, Divergence and curl. | 10 |
| 4 | Green's theorem- Tangential and Normal form, Evaluate line integrals using Green's theorem, Surface integrals, Stokes' theorem. | 10 |
| | **TOTAL** | 40 |

**Book References:**


1. Malik, S.C. & Arora, Savita (2017). Mathematical Analysis, New Age International Private Limited.
2. Marsden, J. E., Tromba, A., & Weinstein, A. (2004). Basic Multivariable Calculus. Springer (SIE). First Indian Reprint.
3. Thomas' Calculus, 14e Paperback, George B. Thomas, Joel Hass, Christopher Heil, Maurice D. Weir, Pearson Education.
4. Prasad Lalji, Advanced Calculus, Paramount Publications, Revised Edition (2015).

## SEMESTER- VIII

## MIC-10: Complex Analysis

### Course Outcomes

**After the completion of the course, the student will be able to:**

**CO1:** Understand the significance of differentiability of complex functions leading to the understanding of Cauchy-Riemann equations.

**CO2:** Evaluate the contour integrals and understand the role of Cauchy-Goursat theorem and the Cauchy integral formula.Expand some simple functions as their Taylor and Laurent series.

| MIC-10: Complex Analysis<br>(4 credits)<br>Full Marks-100 | | |
|---|---|---|
| **Unit** | **Topics to be covered** | **No. of Lectures** |
| 1 | Introduction to complex number and geometrical interpretation, algebra of complex numbers, functions of complex variables, limit of a complex function, continuity and uniform continuity, differentiability, Analytic and regular function, Cauchy-Riemann equation and it's applications. | 10 |
| 2 | Exponential function, logarithmic function, Branches, trigonometric and hyperbolic functions, derivatives of functions, Definite integrals of functions, Contours, Contour integrals and its examples. | 10 |
| 3 | Complex integration, Cauchy's theorem, Cauchy's Goursat theorem (Statement only), primitives, Cauchy's integral formula, Cauchy's integral formula for the derivative of an analytic function, Morera's theorem. | 10 |
| 4 | Convergence of sequences and series, Taylor series and its examples; Laurent series and its examples, Absolute and uniform convergence of power series. | 10 |
| | **TOTAL** | 40 |

**Book References:**


1. Brown, James Ward, & Churchill, Ruel V. (2014). Complex Variables and Applications (9th ed.). McGraw-Hill Education. New York.
2. S. Ponnusamy, (2011) Foundation of complex Analysis, Alpha Science International Ltd. UK.
3. Bak, Joseph & Newman, Donald J. (2010). Complex analysis (3rd ed.). Undergraduate Texts in Mathematics, Springer. New York.
4. Zills, Dennis G., & Shanahan, Patrick D. (2003). A First Course in Complex Analysis with Applications. Jones & Bartlett Publishers, Inc.
5. Mathews, John H., & Howell, Rusell W. (2012). Complex Analysis for Mathematics and Engineering (6th ed.). Jones & Bartlett Learning. Narosa Delhi. Indian Edition.