# Syllabus
# for
# 2-year of Four Semesters
# M.A./M.Sc. in Mathematics
# under
# NEP 2020

***(Effective from the Academic Year 2026– 2027 and onwards)***

**Department of Mathematics**
**Bankura University**
**Bankura**

**BANKURA UNIVERSITY**

**Department of Mathematics**

Syllabus of 2-year M.Sc. in Mathematics under NEP 2020

[**With effect from AY 2026-27**]

There would be two PG programmes in Mathematics: 2-year and 1-year M.Sc. in Mathematics. The duration of 2-year M.Sc. programme in Mathematics shall be of two years consisting of four semesters each of six months duration leading to Semester-I, Semester-II, Semester-III and Semester-IV examinations at the end of each semester while the duration of 1-year M.Sc. programme in Mathematics shall be of one year consisting of two semesters each of six months duration leading to Semester-I, and Semester-II examinations at the end of each semester. Syllabus for 2-year and 1-year M.Sc. in Mathematics is hereby framed according to UGC guidelines on NEP 2020.

Total marks (total credits) for 2-year M.Sc. programme is 1000 (80) with 250 marks (20 credits) in each of the $1^{st}$, $2^{nd}$, $3^{rd}$and $4^{th}$semesters comprising of five papers each of 50 marks (4 credits). There shall remain a course of 4 credits of nature no evaluative in Semester IV on Indian Knowledge Systems (IKS). There shall be a Generic Elective course in Semester II. This course should study by students from disciplines other than Mathematics. In Semesters III & IV, 50% of total weightage i.e., 250 marks (20 credits) should be theoretical and remaining 50% i.e., 250 marks (20 credits) should be research oriented. In each theoretical course, 20% marks of total marks of the course are allotted for Internal Assessment. The teacher(s) of the concern course will evaluate the internal assessment. All the students in Mathematics will have to take the compulsory core courses along with some elective courses as distributed by the department, one generic elective and research course over four semesters. The course on IKS shall have internal assessment only, and so, credit earned from these courses shall not be considered while preparing the finalresult. However, the candidates are required to be successful to obtain "**Satisfactory"**(as against "**Not Satisfactory")** grade to become eligible for the fourth semester examination/award of the M.Sc. degree.

The major elective courses that will run in a particular year in Semester-III &Semester-IV will be decided by the Department. The students have to give options for taking two major electives in each of the last two semesters from the clusters of elective courses offered in those semesters. Students have to take same title (if arises) of major elective courses both in Semester-III and Semester-IV. The option norm for selection of major elective courses is to be framed by the Department in each year based on the SGPA/CGPA available from the previous semester(s) of the students. However, the distribution of students to the research based courses will be equally divided among the faculty members of the department as far as practicable.

**Programme Objectives (PO):**

**PO1**: Mathematical Knowledge: Apply the knowledge of mathematics to the solutions of complex problems in academia and in real life.

**PO2**: Problem analysis: Identify, formulate, analyze/solve problems leading to conclusions using principles of mathematics.

**PO3**: Design/development of solutions: Design and develop methods and procedures for solutions of complex problems which meet the specified needs in industry, academia and real life.

**PO4**: Conduct investigations of complex problems: Use research-based knowledge and research methods including theory, experiment and computation; analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

**PO5**: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern mathematical tools including prediction and modeling to complex mathematical activities with an understanding of the limitations.

**PO6**: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

**PO7**: Communication: Communicate effectively on scientific activities with the scientific community and with the society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. For example, the courses research works are such course where the students work on a "research" problem in which they do the literature survey, solve the problem, write report and present the outcome in front of the audience. This leads to the PO mentioned here.

**PO8**: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of scientific & technological change. As one can see in the Syllabus, it contains courses other than that class-room teaching (listening/reading/learning/writing), the skill development courses, and research oriented course. All these leads to what is mentioned in this PO.

**PO9**: Knowledge on Indian Mathematics: Impartation of vast knowledge on Indian Knowledge Systems makes students to feel proud to be a truly Indian.

**Programme Specific Outcomes:** The Department of Mathematics offers exciting opportunities to talented students holding a Bachelor's degree for acquiring a rigorous and modern education in mathematics and for pursuing master's degree in both pure and applied mathematics. As a part of the Programme, the student as to complete 84 credits of courses including a "Term Paper", whose major part is kind of academic research (and does not involve class room teaching),in a chosen area of pure or applied mathematics. This Program will introduce the students to modern as well as classical topics of mathematics, will help in acquiring thinking skills and to prepare him/her to undertake cutting-edge research in a Ph.D. Program.

**Career Opportunities:** This program will enable the students to take part and qualify for the state and national level examinations such as SET, NET, GATE, NBHM etc. After completion of this program, the students are well prepared for higher education such as Ph.D. program and for a variety of jobs both in the industry and in academic institutions all over the world.

**Contents**

**Structure of the syllabus of 2-year M.Sc. in Mathematics**

| Semester with duration | Course Code | Course Title | Class hrs/week | No. of Hours per week | | | Credit | Marks | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | I.A. | ESE |
| Semester I of Six Months | CCF/Math-101/MJC-1 | Abstract Algebra | 04 | | | | 04 | 10 | 40 |
| | CCF/Math-102/MJC-2 | Real Analysis | 04 | | | | 04 | 10 | 40 |
| | CCF/Math-103/MJC-3 | Ordinary Differential Equations and Partial Differential Equations | 04 | | | | 04 | 10 | 40 |
| | CCF/Math-104/MJC-4 | Techniques of Applied Mathematics | 04 | | | | 04 | 10 | 40 |
| | CCF/Math-105/MJC-5 | Numerical Analysis with Practical using Matlab/Python | 04 | | | | 04 | 04 | 16 (Th.) +30 (P) |
| | **Total in Semester - I** | | **20** | | | | **20** | **50** | **200** |
| Semester II of Six Months | CCF/Math-201/MJC-6 | Topology | 04 | | | | 04 | 10 | 40 |
| | CCF/Math-202/MJC-7 | Modules & Linear Algebra | 04 | | | | 04 | 10 | 40 |
| | CCF/Math-203/MJC-8 | Classical Mechanics and Introduction to Special Theory of Relativity | 04 | | | | 04 | 10 | 40 |
| | CCF/Math-204/MJC-9 | Introduction to Machine Learning & Computational Methods for PDEs | 04 | | | | 04 | 10 | 40 |
| | CCF/Math-205/GE-1* | Computer Applications | 04 | | | | 04 | 10 | 40 |
| | **Total in Semester - II** | | **20** | | | | **20** | **50** | **200** |

* For students of disciplines other than Mathematics

*Meaning of the symbols: L = Lecture, T = Tutorial, P = Practical, I.A. = Internal Assessment, ESE= End Semester Examination, Th. = Theory.*

**Semester I**

**Course: CCF/Math-101/MJC-1**

**Abstract Algebra**

**Course Objectives:** The main objective of this course is to give a deep insight of group theory and ring theory. Converse of Lagrange's theorem will be discussed there in a great extent with some kind of special groups and their characterizations. This course also covers a vast area of ring theory for their further use.

**Course Specific Outcomes:** After completion of this course a student would have a clear idea of characterizations of groups and factorization domains. Students will be able to construct finite fields from a PID. They will also develop the foundational knowledge required to study Galois theory and its applications in determining the solvability of polynomial equations by radicals.

***Total Lectures: 50*** **(*Marks – 50*)**

**Course Contents:**

Automorphism and inner automorphism, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, automosphism groups of various commutative and non-commutative finite groups, characteristic subgroups of a group and its properties, commutator subgroup of a group and its properties.

Properties of external direct products, the group of units modulo n as an external direct product, internal direct products, Fundamental Theorem of finitely generated abelian groups, invariant factors and elementary divisors.

Group action on a set, orbits, stabilizers and kernels, Generalized Cayley's Theorem, extended Cayley's Theorem, Index Theorem, Burnside Theorem, groups acting on themselves by conjugation, class equation of various groups, p-groups, Cauchy's Theorem, converse of Lagrange's Theorem for finite Abelian groups, Sylow's Theorems and some of their applications in checking non-simplicity of groups.

Normal and subnormal series, composition series, solvable groups, nilpotent groups, Jordan-Hölder Theorem and its applications.

Quotient field of an integral domain, divisibility theory in domains, principal ideal domain, factorization domains, Euclidean domain, polynomial rings, division algorithm in polynomial rings, Gauss' Theorem, irreducibility in polynomial rings, Eisenstein's criterion, fields as quotients of polynomial rings with the help of irreducible elements.

**References:**

1. D. S. Dummit and R. M. Foote, *Abstract Algebra, 3rd Edition,* Wiley India Pvt, 2011.

2. D. S. Malik, J. M. Mordeson, J. N. Mordeson and M. K. Sen, *Fundamentals of Abstract Algebra*, McGraw-Hill, 1997.

3. I. N. Herstein, *Topics in Algebra*, 2nd Edition,Wiley India Pvt. Limited, 2022.

4. J. A. Gallian, *Contemporary Abstract Algebra,9th Edition,*Cengage India Private Limited, 2019.

5. T. W. Hungerford,*Algebra,* Springer, 1974.

6. M. Artin, *Algebra, 2nd Edition,* Pearson, 2024.

7. Joseph J. Rotman, *An Introduction to the Theory of Groups, 4th Edition***,** Springer Verlag, 1995.

**Evaluation:**

End semester examination – 40 marks (05 questions to be answered out of 08 questions each carrying 08 marks). Internal Assessment – 10 marks.

**Course: CCF/Math-102/MJC-2**

***Real Analysis***

**Course Objectives:** The main objective of this course is to introduce the notions of measurable sets by Lebesgue outer measure of a set, measurable functions and study their various properties. The concept of Lebesgue integration as a generalization of Riemann integration is also introduced and cultivated here.

**Course Specific Outcomes:** After completion of this course a student would mainly have

- a vast knowledge of measurable sets, measurable functions
- a clear concept of Lebesgue integration
- an idea how to construct non-measurable sets.

***Total Lectures: 50*** **(*Marks – 50*)**

**Course Contents:**

Functions of Bounded Variation and their properties. (4L)

Riemann-Stieltjes integration, Necessary and sufficient conditions of RS integrability, Some basic theorems. RS Integral as limit of a sum, RS integral to Riemann integration, mean value theorem, and Integration by parts and their applications. (9L)

Lebesgue outer measure, measurable sets and their properties, Cantor's set and its measurability, Borel sets and their measurability, existence and construction of non-measurable sets, properties of non-measurable sets, Lebesgue measure. (15L)

Lebesgue measurable functions and their properties, algebraic properties of measurable functions, characteristics function and its measurability, sequence of measurable functions, Egoroff's theorem, Applications of Lusin Theorem. (10L)

Simple and Step Functions, Lebesgue integral of simple and step functions, Lebesgue integral of a bounded function over a set of finite measure, Bounded Convergence Theorem, Lebesgue integral of non-negative function, Fatou's Lemma, Monotone Convergence Theorem. The General Lebesgue integral:

Lebesgue Integral of an arbitrary Measurable Function, Lebesgue Integrable functions. Dominated Convergence Theorem, Riemann Integral as Lebesgue Integral. (12L)

***References:***


1. I. P. Natanson, *Theory of Functions of a Real Variable,* Vol. I, Dover Publications, 2016
2. R.G. Bartle, *The Elements of Integration and Lebesgue Measure*, John Wiley & Sons, Inc., New York, 1995
3. A. Mukherjea and K. Pothoven, *Real and Functional Analysis*, Plenum Press, New York, 1978
4. Bernard R. Gelbaum, John M. H. Olmsted, *Counterexamples of Analysis*, Dover Publications Inc., 2003
5. C. Goffman, *Real Function,* Vol. 8, Prindle, Weber & Schmidt, 1953
6. J. C. Burkil, *The Lebesgue Integral,* Cambridge University Press, 2004
7. R. R. Goldberg, *Methods of Real Analysis***,** Oxford and IBH Publishing, 2020
8. H. L. Royden, *Real Analysis*, Pearson Education, 4th Edition, 2015
9. B. V. Limaye, *Functional Analysis,* New Age International (P) Ltd., 2004
10. B. Z. Vulikh *–A Brief Course in the Theorey of Functions of a Real Variable,* Ed Conroy Book, 1976
11. B. K. Lahiri and K. C. Roy, *Real Analysis,* World Press, 1988
12. T. M. Apostol, *Mathematical Analysis,* Addition Wesely, 5th Edition, 1981
13. S. C. Saxena and S. M. Shah, *Introduction to Real Variable Theory,* Intext Educational Publishers, 1972
14. C. W. Scwartz – *Measure, Integration and Function spaces, World Scientific Publishing Co. P. Ltd., 1994*
15. W. Rudin- *Real and complex analysis,* McGraw Hill Educatio, 3rd Edition, 2017
16. P. K. Jain, V. K. Gupta and P. Jain- *Lebesgue Measure and Integration,* New Age International (P) Ltd., 2011


**Evaluation:** End semester examination: 40 marks (05 questions to be answered out of 08 questions carrying 08 marks of each).

Internal Assessment: 10 marks.

## Paper: Math-xxx

### *Ordinary Differential Equations and Partial Differential Equations*

**Course Objectives:** The aim of this course is to teach the students about Ordinary Differential Equations (ODEs)(both scalar and system of ODEs, linear and nonlinear ODEs), existence & uniqueness of solution, phase plane, critical points, stability of solutions. They also learn about Partial Differential Equations (PDEs), their degree& order, classification, existence and uniqueness of solution and different analytical methods for solving PDEs.

**Course Specific Outcomes:** After completion of this course, the students learn about:

- Linear and nonlinear (system of) ODEs, existence & uniqueness of solution with the help of Picard's and Piano's theorems,
- Solution techniques for both initial and boundary value problems for ODEs, stability of solutions,
- Strum-Liouville problem, Green's functions and orthogonal properties of solutions of Strum-Liouville problem,
- PDEs of first and second order, their classification, methods of solution of linear and nonlinear PDEs,
- Cauchy problem, method of characteristic, fundamental solution, Green's functions.

***Total Lectures: 50*** **(*Marks – 50*)**

**Course Contents:**

**ODE**: First order system of equations: Well-posed problems, simple illustrations. Peano's and Picard's theorems (statements only). (2L)

Linear systems, non-linear autonomous system, phase plane, critical points, stability, Liapunov stability, undamped pendulum.(5L)

Linear ordinary differential equations, generalized solution, fundamental solution, inverse of a differential operator.

Nonhomogeneous ordinary differential equations, Two-point boundary value problem for a second-order linear nonhomogeneous ODE. Self adjoint operator. Sturm-Liouville problem. Construction of Green's functions with examples. Orthogonal property of solutions of Sturm-Liouville problem.

Analogy between linear simultaneous algebraic equations and linear differential equation. (3L)

**Partial Differential Equation:** Partial Differential Equation of the first order. Cauchy's problem for the first order equations. Linear first order equations. Lagrange's equation. General solution. Integrals passing through a given curve. Orthogonal surfaces. Nonlinear PDE of the first order. Cauchy's method of Characteristics. Charpit's method. Examples.(7L)

Second order linear PDE: Classification, reduction to normal form; characteristic curves.

Solution of linear hyperbolic equations by Riemann method. Riemann-Green's function. (7L)

**Laplace equation**: Occurrence of Laplace equations. Boundary value problems: Dirichlet (interior and exterior) and Neumann (interior and exterior). Separation of variables. Green's function for Laplace's equation. Its properties and methods of construction. (10L)

**Wave equation**: Occurrence of wave equation. D'Alemberts solution. Riemann-Volterra solution of one dimensional wave equation. Domain of influence and domain of dependence. Solution by separation of variables method. Solution by method of integral transforms. Vibrating membranes. (8L)

**Diffusion equation:** Occurrence of diffusion equation. Elementary solutions. Solution by integral transform technique. Separation of variables for rectangular and circular plate problems. Finding the elementary solution of diffusion equation. (8L)

***References:***

1. E. A. Coddington and N. Levinson, *Theory of Ordinary Differential Equations,* McGraw-Hill, 1955
2. G. Teschl, *Ordinary Differential Equations and Dynamical Systems,* American Mathematical Society, 2012

3. I. N. Sneddon, *Elements of Partial Differential Equations,* Dover Publications, 2013.
4. P. Prasad and R. Ravindran, *Partial Differential Equations,* Wiley, 1984.
5. U. Ascher and L. Petzold, *Computer Methods for Ordinary Differential Equations and Differential Algebraic Equations,* Society for Industrial and Applied Mathematics 1998
6. W. E. Williams, *Partial Differential Equations,* Clarendon Press, 1980
7. B. Epstein, *Partial Differential Equations,* R. E. Krieger Publishing Company, 1975
8. C. R. Chester, *Techniques in Partial Differential Equations,* McGraw-Hill, 1970

**Evaluation:** End semester examination – 40 marks (05 questions to be answered out of 08 questions carrying 08 marks of each).
Internal Assessment – 10 marks.

**Course: CCF/Math-104/MJC-4**
**Techniques of Applied Mathematics**

**Course Objectives**: The aim of this course is to introduce Laplace, and Fourier transforms to the students, requirements on the functions for those methods to be applicable and the applications. Students also learn about special functions in this course. The other important mathematical topic they learn is about integral Equations; their origin and classification, existence & uniqueness of solution of Volterra and Fredholm integral equations.

**Course Specific Outcomes**: After completion of this course, the students learn about:

- Students will gain a range of techniques employing the Laplace and Fourier Transforms.
- Special functions, Singular point, Legendre polynomial, Rodrigue's formula,
- Legendre functions, Bessel functions, solution of Legendre, Laugurre and Bessel equation,
- Origin and classification of integral equations, Relation of initial and boundary value problem, Existence and uniqueness of Volterra, Fredholm& Abel's integral equations.

***Total Lectures: 50*** (***Marks – 50***)

**Course Contents:**

**Integral Transforms:** Impulse Function, Dirac delta function, Heaviside Unit Function, It’s properties, Fourier Transform and its properties, Inversion formula of Fourier transform; Convolution theorem; Parseval’s relation (statement only). Finite Fourier transform and its inversion formula. Applications.

Laplace transform and its properties. Inversion by analytic method and by Bromwitch path. Lerch’s theorem. Convolution theorem; Applications of Fourier and Laplace transform. (16L)

**Special functions:** Regular and irregular singularity, Singularity of a second order linear differential equation, Frobenius’ method, solution about regular singularity with examples, Solution of Hypergeometric equation. Confluent Hypergeometric equation, Properties of Hypergeometric function, Derivatives and Integral representations, Pochhammer symbol.

Legendre polynomial, its generating function; Rodrigue’s formula, recurrence relations and orthogonality properties; Associated Legendre functions, Legendre function of second kind, Recurrence relations, Expansion of a function in a series of Legendre Polynomials.

Bessel functions of first and second kind, Properties of Bessel's function, its generating function, Recurrence relations, Modified Bessel functions, orthonormality. (17L)

**Integral Equations**: Linear integral equations of the first and second kind of Fredholm and Volterra type; Solution by successive approximations; Solution of equations with separable kernels. Iterated kernels, degenerate kernel, symmetric kernel, Resolvent kernel, Neumann series, Reduction of Initial value and boundary value problems to integral equations, Existence and Uniqueness of solutions of Fredholm and Volterra Integral equations; examples, Laplace transform method, Examples, Characteristic numbers and eigenfunctions Singular integral equation, Solution of Abel's integral equation. (17L)

***References:***

1. B. Davies, *Integral Transforms and Their Applications,* Springer New York, 2013.
2. J. W. Miles, *Integral Transforms in Applied Mathematics*, Cambridge University Press, 1971.
3. Larry C. Andrews and Bhimsen K. Shivamoggi, *Integral Transforms for Engineers,* SPIE-The International Society for Optical Engineering, 1999.
4. Ian. N. Sneddon, *The Use of Integral Transforms*, McGraw-Hill, 1972
5. E. D. Rainville, *Special Functions,* Macmillan, 1960
6. Ian. N. Sneddon, *Special Functions of mathematical Physics & Chemistry, Oliver & Boyd, 1966.*
7. N. N. Lebedev, *Special Functions and Their Applications*, Dover Publications, 1972
8. S. G. Mikhlin, *Integral Equation,*Pergamon Press, 1964.
9. F. G. Tricomi, *Integral Equation*, Dover Publications, 2012.
10. W. V. Lovit, *Linear Integral Equations*, Dover Publishers, 2014.

**Evaluation:** End semester examination – 40 marks (05 questions to be answered out of 08 questions carrying 08 marks of each).
Internal Assessment – 10 marks.

**Course: CCF/Math-105/MJC-5**

**Numerical Analysis with Practical using Matlab/Python**

**Course Objectives:** The aim of this course is to teach the students about different methods for finding numerical solution of different mathematical problems, convergence criteria of such solutions, analysis of the numerical methods, errors involved in the solution and to write computer program using Matlab/Python for finding numerical solutions.

**Course Specific Outcomes:** After completion of this course, a student will be able to:

- Derive numerical methods for approximating the solution of different problems of mathematics,
- Analyze the error incumbent in any such numerical approximation,
- Implement a variety of numerical algorithms using appropriate technology
- Compare the viability of different approaches to the numerical solution of problems arising in solution of linear and nonlinear system of equations, eigen value problems, Ordinary and Partial

differential Equations, etc.

- Write any source program to compute the numerical solutions of the mathematics problems, which arise in the research studies with applications to engineering, physical, biological or social sciences.

**Group A**

**Numerical Analysis**

**Total Lectures: 20** **(Marks – 20)**

**Course Contents:**

**Solving system of linear equations:** Existence & uniqueness of solutions. Gauss Elimination, LU decomposition, Solution using LU decomposition. (4L).

**Iterative Methods:** Review of iterative methods, SOR method, Gauss Jacobi iteration, Gauss-Siedel Iteration. Operational count: operational counts of exact methods and iterative methods, Multigrid Methods (5L).

**System of Non-Linear Equations:** Fixed point theory, Conditions of convergence, Newton's Method, Variations of Newton's method. (4L)

**Interpolation:** Spline interpolation (3L)

**ODE:** IVP: Concept of single step and multistep methods; Review of solution methods for IVP, Generating solution curve of IVP using Runge-Kutta methods. Adam-Bashforth-Moulton and Milne's predictor corrector method to solve first order initial value problems. (4L)

**Group B**

**Numerical Analysis Practical using Matlab/Python**

**Total Lectures: 30** **(Marks – 30)**

**Course Contents:**

**Practical: Using Matlab/Python**

**Matrix Algebra:** Generating matrix, Matrix manipulation, Deleting rows and columns, Creating special matrices, Symmetric matrix, The transpose, determinant and inverse of a Matrix, Mathematical operations on Matrices. Converting a Matrix into its row reduced echelon form/Lower or Upper triangular form if non-singular square matrix, Calculation of Determinant of a Square matrix, Detection whether a square matrix is singular or not. Finding eigenvalues and eigenvectors of non-singular square matrix. (8L)

**Solving a system of linear equations**:

Revision of Direct methods: Gauss Elimination, LU decomposition. (4L)

Iterative methods: Gauss Jacobi iteration, Gauss-Siedel Iteration, SOR method. (6L)

**Solving System of Non-Linear Equations:** Solution of a system of non-linear equations by fixed point method Newton's Method. (4L)

**ODEs:** Using Runge-Kutta methods (order 2 and 4) for solving a differential equation with proper initial condition and plotting the solution. Solving simultaneous first order ordinary differential equations. (6L)

**Interpolation:** Spline interpolation (2L)

**References:**

1. F. B. Hildebrand, *Introduction to Numerical Analysis*, Courier Corporation, 1987.
2. B. P. Demidovich and I. A. Maron, *Computational Mathematics*, Mir Publishers, 1981
3. M. K. Jain, S. R. K. Iyengar and R. K. Jain, *Numerical Methods for Scientific and Engg. Computation*, New Age Techno Press, 2012
4. P. Niyogi, *Numerical Analysis and Algorithms*, Tata McGraw-Hill, 2003
5. J. B. Scarborough, *Numerical Analysis*, Johns Hopkins Press, 1930
6. K. E. Atkinson, *Numerical Analysis*, Wiley India Pvt. Limited, 2008
7. R.L. Burden and J.D. Faires, *Numerical Analysis*, Cengage India Private Limited, 2012.
8. D.M. Etter, *Introduction to MATLAB for Engineers and Scientists*, Prentice-Hall.
9. R. Pratap, *Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers*, Oxford University Press.
10. A. Gilat, *MATLAB*: *An Introduction with Applications*, New York: Wiley.
11. F. Laurene, *Applied Numerical Analysis Using MATLAB*, Prentice-Hall.
12. J. P. William, *Introduction to MATLAB for Engineers*, New York: McGraw-Hill.

**Evaluation:** Group A: End semester examination – 16 marks (02 questions to be answered out of 03 questions carrying 08 marks of each).

Internal Assessment – 04 marks.

Group B: Practical examination – 30 marks (Programming using Matlab/Python-15 marks, Practical notebook-08 marks, Viva-voce- 07 marks).

## Semester II
## Course: CCF/Math-201/MJC-6
## Topology

**Course Objectives:** After the introduction of topological spaces, in this course, to study various properties and interconnections of different topological spaces is the main objective here. Connectedness, compactness and separation axioms will be studied here in details.

**Course Specific Outcomes:** After completion of this course a student

- would have a vast knowledge of various topological spaces which they can use for their further study
- can see various structures studied before as special cases of topological spaces.

***Total Lectures: 50*** **(*Marks – 50*)**

**Course Contents**:

**Topological spaces:**

Cardinal number, continuum hypothesis, axiom of choice, Konigsberg bridge problem in introduction of topological spaces, topology on a set, examples of topologies (topological Spaces): discrete topology, indiscrete topology, finite complement topology, countable complement topology, topologies on the real line, finer and coarser topologies, basis and sub basis for a topology, neighbourhood system, product topology for finite number of topological spaces, subspace of a topology, order topology., interior points, limit points, derived set, boundary of a set, closed sets, closure and interior of a set, Kuratowski closure operator and the generated topology. Filter and its convergence in topological spaces. (16L)

**Functions:**

Continuous functions, rules for constructing continuous functions: inclusion map, composition, by restricting the domain, by restricting/expanding the range, Pasting lemma, open maps, closed maps and homeomorphisms. (infinite) product topology: sub basis for product topology defined by projection maps, box topology, quotient topology, metric topology. (8L)

**Countability Axioms and Separation axioms:** T0, T1, Hausdorff spaces, regular spaces, completely regular spaces, normal spaces, $T2$, $T3$, $T4$–spaces, completely regular spaces, Tychonoff spaces: their properties and relationships, Urysohn's lemma, Uryshon's Metrization Theorem, Tietze's extension theorem (Statement only). (16L)

**Connectedness and Compactness:**

Connected and path connected spaces: definitions, examples and its properties, connected subsets of the real line, components and path components, local connectedness. compact space, characterization of compact spaces in terms of finite intersection properties, continuous image of compact spaces, compact subsets of the real line, Heine-Borel theorem, locally compact space. (10L)

***References:***


1. R. Engelking, *General Topology*, Heldermann, Berlin, 1989
2. J. R. Munkres, *Topology,* Prentice-Hall of India Pvt. Ltd, 2nd Edition, 1999
3. W. J. Thron, *Topological Structures,* Holt, Rinehert and Winston, Inc., 1966
4. K. D. Joshi, *Introduction toGeneral Topology,* New Age International Pvt. Ltd., 2017
5. J. L. Kelley, *General Topology,* Springer, 2nd Edition, 1975
6. G. F. Simmons, *Introduction to Topology & Modern Analysis*, *McGrow Hill Education, 2017*
7. S. Willard, *General Topology,* Dover Publications Inc., 2004
8. S. A. Gaal, *Point Set Topology*, Academic Press Inc., 1964
9. J. A. Seebach and L. Steen, *Counterexamples in Topology,* Dover Publications Inc., 1995


**Evaluation:** End semester examination: 40 marks (05 questions to be answered out of 08 questions carrying 08 marks of each).

Internal Assessment – 10 marks.

**Course: CCF/Math-202/MJC-6**

**Modules & Linear Algebra**

**Course Objectives:** The main objective of this course is not only to give a basic idea of module theory but also its application to find possible canonical forms of a linear operator on a finite dimensional vector space.

**Course Specific Outcomes:** After completion of this course a student would have a clear knowledge of modules and their algebraic properties, diagonalizability of linear operators and bilinear forms. Students will be able to realize the inner play of mathematics in constructing possible canonical forms of a linear operator on a finite dimensional vector space instead of learning only the working formulae.

***Total Lectures: 50*** **(*Marks – 50*)**

**Course Content:**

Definitions of modules and examples, submodules and quotient modules, operations on submodules, module homomorphisms, cyclic modules, free modules, direct sums and direct summands, Noetherian modules, free modules over a PID, relation between torsion-free and free modules, structure theorem for finitely generated modules over a PID, primary decomposition, cyclic decomposition. (17L)

Minimal polynomial of a linear operator on a finite dimensional vector space, invariant subspaces, diagonalizability and triangulability, projection operator, direct sum decomposition, invariant direct sums, Primary Decomposition Theorem, Cyclic Decomposition Theorem, invariant factors and elementary divisors, Rational Canonical Form, Jordan Canonical Form, semisimple operator. ( 17L)

F[x]-module V associated with a linear operator over finite dimensional vector space V over a field F, connections between V as a vector space over F and as a module over F[x]; translation from vector space setting to module setting and vice-versa.

Application of canonical forms to differential equations. (10L)

Bilinear Form and its matrix representation, symmetric bilinear form, quadratic form, classification of quadric forms, Sylvester's law of inertia. (6L)

**References:**

1. K. Hoffman and R. A. Kunze*, Linear Algebra,* Prentice-Hall, 1971.
2. Steven Roman*, Advanced Linear Algebra*, 3rd Edition, Springer, 2007.
3. S. H. Friedberg, A. Insel and L. Spence*, Linear Algebra*, Pearson, 2003.
4. S. Lang, *Linear Algebra,* Springer, 1987.
5. S. Kumaresan*, Linear Algebra as a geometric approach,* PHI Learning, 2001.
6. D. S. Dummit and R. M. Foote, *Abstract Algebra, 3rd Edition,* Wiley India Pvt, 2011.
7. T. W. Hungerford*, Algebra,* Springer, 1974.
8. M. Artin, *Algebra, 2nd Edition,* Pearson, 2024.
9. Maclane and Birkoff, *Algebra, 3rd Edition,* Orient Blackswan, 2013.

**Evaluation:**

End semester examination – 40 marks (05 questions to be answered out of 08 questions each carrying 08 marks). Internal Assessment – 10 marks.

**Course: CCF/Math-203/MJC-8**

**Classical Mechanics and Introduction to Special Theory of Relativity**

**Course Objectives:** The aim of this course is to teach the students about Virtual work, D'Alembert's principal, Lagrangian formulation of Dynamics, Generalized coordinates, calculus of variation, configuration space and system point, generating functions, canonical transformations, Poission and Lagrange bracket, theory of small oscillations and special theory of relativity.

**Course Specific Outcomes:** After completion of this course, the students learn about:

Constraints, basic problems with constraints, virtual work, D'Alembert's principal, work energy relations.

- Lagrangian formulation of dynamics, Concept of cyclic or ignorable coordinates, calculus of variation.
- Invariance of Euler-Lagrange equation, Theory of small oscillations,
- Special Theory of Relativity, its postulates, Lorentz transformation, length contraction, time dilation.
- To acquire the advance knowledge of mechanics.

**Total Lectures: 50** **(Marks – 50)**

**Course Contents:**

Constraints, Basic problems with constraint forces, Principle of Virtual Work, D'Alembert'sprinciple, Work energy relation for constraint forces of sliding friction. (3L)

Degrees of freedom, Generalized coordinates, Generalized velocity, Generalized force, Generalized momentum and energy. Lagrange's equations of first and second kind (holonomic and nonholonomic system), Kinetic energy function, Hamilton's canonical equations, Hamiltonian, Theorem on total energy, linear generalized potentials. Hamilton's principle and principle of least action, Double pendulum, Atwood's machine. (8L)

Cyclic or ignoration of co-ordinates, Routh's process for the ignorable co-ordinates. (3L)

Calculus of variation: Variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema, Variational methods for boundary value problems in ordinary and partial differential equations, Brachistochrone problem. (6L)

Generating Function, Canonical transformations, Hamilton-Jacobi Method, Solution of Harmonic Oscillator problem by Hamil Jacobi method, theory of small oscillations, Lagrange's and Poisson brackets, Invariance of Lagrange's and Poisson brackets, it's properties, integral invariants of Poincare, Canonical transformations, Differential forms and generating functions, Liouville's theorem, Jacobi's

Identity, Poisson's Theorem, Jacobi-Poisson theorem. (12L)

Two-dimensional motion of rigid bodies, Principle of linear momentum, Principle of angular momentum, Euler's dynamical equations for the motion of a rigid body about an axis, Torque free motion, Motion of a symmetrical top, Eulerian angles, Theory of small oscillations, Motion of a particle relative to rotating earth, Foucault's pendulum. (12L)

**Special Theory of Relativity**: Postulates of Special Relativity, Lorentz Transformation, Consequences of Lorentz Transformation, Lorentz group, Length contraction, time dilation, transformation of velocity, law of composition of velocity, Four dimensional spaces. (6L)

**References:**

1. F. Chorlton, *A Text Book of Dynamic,* Ellis Horwood, Chichester,2nd edition 1983.

2. Synge and Griffith, *Principles of Mechanics*, McGraw-Hill Book Company, 1949.

3. D. T. Greenwood*,* *Classical Dynamics*, DovarPubliation, Inc., New York, 1977,

4. E. T. Whittaker, *A Treatise on the Analytical Dynamics of Particles and Rigid Bodies*, Cambridge University Press, 2012.

5. K. C. Gupta, *Classical Mechanics of Particles and Rigid Bodies*, New Age International Publishers, 2018.

6. R. D. Gregory, *Classical Mechanics, Cambridge University Pres*s, Cambridge University Press, 2006.

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8. F. Gantmacher, *Lectures in Analytical Mechanics*, Mir Publishers, Moscow, 2013.

9. H. Goldstein, C. Poole and J. Safko, *Classical Mechanics, 3 rd Edition*, Pearson, 2011.

10. N.C. Rana and P.S.Joag, *Classical Mechanics*, McGraw-Hill Company, 2001.

11. M. R. Spiegel, *Theoretical Mechanics*, McGraw-Hill Company, 1982.

12. B. D. Sharma, B.S. Tyagi, B. Nand, *Dynamics of Rigid Bodies*, KedarNath Ram Nath, 2020.

13. V. I. Arnold, *Mathematical Methods of Classical Mechanics- Second Edition*, Translated by K. Vogtmann and A. Weinstein- Springer-Verlag,1991.

14. Louis N. Hand and Janet D. Finch, Analytical Mechanics, Cambridge University Press, 1998.

**Evaluation:** End semester examination – 40 marks (05 questions to be answered out of 08 questions carrying 08 marks of each.

Interal Assessment – 10 marks,

**Paper: Math-xxx**

***Introduction to Machine Learning & Computational Methods for PDEs***

**Course Objectives:** To understand the basic theory underlying machine learning, types, and the process. To become familiar with data and visualize univariate, bivariate, and multivariate data using statistical techniques and dimensionality reduction. To understand various machine learning algorithms such as similarity-based learning, regression, decision trees, and clustering. To familiarize with learning theories, probability-based models, and reinforcement learning, developing the skills required for decision-making in dynamic environments.
Also, to teach the students about discretization techniques to find approximate solutions of differential equations, different types of errors involved in such solutions, their measures and practical applications.

**Course Specific Outcomes:** After completion of this course, students will:

- Differentiate between supervised and unsupervised learning tasks.
- State the need of preprocessing, feature scaling and feature selection.
- Formulate classification, regression and clustering problems as optimization problems
- Implement various machine learning algorithms learnt in the course.
- Students will learn discretization techniques for the solution of ordinary differential equations and partial differential equations; stability, consistency and convergence criteria of different discretization methods; practical application of the methods to some well-known PDEs arising from mathematical modelling of real-life problems.

**Group – A**

***Introduction to Machine Learning***

***Total Lectures: 20*** **(*Marks --20*)**

**Course Contents:**

Introduction: Basic definitions and core concepts of ML, the history of ML, Classification of ML Techniques: Key elements, supervised, unsupervised and reinforcement learning, real world applications of ML.
Data engineering and Preprocessing: Feature scaling, feature selection methods. dimensionality reduction (Principal Component Analysis), class balancing, outlier detection and removal.
Regression: Linear regression with one variable, linear regression with multiple variables, gradient descent, over-fitting, regularization. Regression evaluation metrics.
Classification: Decision trees, Naive Bayes classifier, logistic regression, k-nearest neighbor classifier, perceptron, multilayer perceptron, neural networks, back-propagation algorithm, Support Vector Machine (SVM). Classification evaluation metrics.

**Group – B**

***Computational Methods for PDEs***

***Total Lectures: 30*** **(*Marks -- 30*)**

**Discretization Methods**: Finite Difference Method for Partial Differential equations; Consistency, stability and convergence; Applications to Elliptic equations, Forward Difference Explicit Methods, Truncation errors for forward Difference Explicit Methods, Crank Nicolson Implicit method, Truncation errors for implicit methods; Applications to parabolic and hyperbolic equations.

***References:***
1. Tom M. Mitchell, *Machine Learning*, McGraw-Hill Education, 2013
2. S Sridhar and M Vijayalakshmi, *Machine Learning*, Oxford University Press, 2021.
3. H. J. Stetter, *Analysis of Discretization Methods for Ordinary Differential Equations,* Springer, 1973.
4. C. A. J. Fletcher, *Computational Fluid Dynamic*, Springer, 2012.
5. P. Niyogi, S. K. Chakraborty and M. Laha, *Introduction to Computational Fluid Dynamics,* Pearson Education India, 2006.

**Evaluation:** End semester examination – 32 marks.
**Group A** - 02 questions to be answered out of 03 questions carrying 08 marks of each.
**Group B** - 02 questions to be answered out of 03 questions carrying 08 marks of each.
Internal Assignment – 08 marks.
Internal Assessment – 10 marks.

**Course: CCF/Math/205/GE-1***

**Computer Applications**

**Course Objectives:** The aim of this course is to teach the students about theory of C-language and Matlab. To understand the basic structure of C-language and MATLAB programming language.

**Course Specific Outcomes:** After completion of this course, the students learn about:

- Basics of C-language and MATLAB software.
- To learn the use of arrays, functions and matrix manipulation
- To acquire skills of plotting graphs using MATLAB
- To acquire problem solving skills of various mathematical problems real-life problems.

**Total Lectures: 50** **(Marks–50)**

**Course Contents:**

Unit 1: Programming Language in C: C Character set, Keywords, Basic data types, Constants, Variables, Operators and Expressions, Assignment Statements, I/O statements. (5L)

Control Statements: Decision making and Looping statements in C, break and continue statements, Example of Simple Programs. (10L)

Unit 2: Subscripted variables: Concept of array variables in programming language, Rules for one-dimensional and two-dimensional subscripted variable in C, String, Example of Simple programs.

Definition of Function, Built-in function, user-defined function, Recursion. (10L)

Unit 3: Basics of MATLAB, MATLAB windows, MATLAB workspace, Data types, MATALB variables, Assignment statements, Arrays, Matrices, String, Cell arrays and structures, General commands, Managing workspace, Mathematical operators, Writing mathematical expressions in MATLAB. (10L)

Unit 4: Creating an Array, Mathematical operations on arrays, Addition, Subtraction, Multiplication. Relational and Logical operators on arrays, Multidimensional arrays.

Generating matrix, Matrix multiplication, The transpose, determinant and inverse of a Matrix, Mathematical operations on Matrices, Symbolic computation.Writing Simple programs. (10L)

Unit 5: Plotting process, Creating a graph, Graph components, Arranging graphs within a figure, Choosing a type of graph to plot, Basic 2-D Plots, Labels, title, legend. (5L)

**References:**

1. E. Balagurusami, *Programming in ANSI C,McGraw Hill Education (India) Private Limited*, 2019

2. Y. P. Kanetkar, *Let us C, BPB Publication*, 2017.

3. D.M. Etter, *Introduction to MATLAB for Engineers and Scientists*, Prentice-Hall.

4. R. Pratap, *Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers*, Oxford University Press.

5. A. Gilat, MATLAB: *An Introduction with Applications*, New York: Wiley.

6. F. Laurene, *Applied Numerical Analysis Using MATLAB*, Prentice-Hall.

7. J. P. William*, Introduction to MATLAB for Engineers*, New York: McGraw-Hill.

8. C. Lopez, *MATLAB programming for numerical analysis*, Apress; 2014.

**Evaluation:** End semester examination – 40 marks (05 questions to be answered out of 08 questions carrying 08 marks of each).

Internal Assessment – 10 marks.