

**Curriculum for Four-Year BS Honours Program**  
**Department of Mathematics**  
**University of Dhaka**



**(Effective for 2023-2024 and onwards)**

**Total Credits: 134 (31+33+35+35)**

## List of Departmental and Non-Departmental Courses for First Year

(31 Credits)

(Effective for 2023-2024 and onwards)

### Departmental Courses (23 Credits)

| Course No.                                  | Course Name                   | Credits   |
|---------------------------------------------|-------------------------------|-----------|
| <b>MTH 101</b>                              | Fundamentals of Mathematics   | 3 credits |
| <b>MTH 102</b>                              | Differential Calculus I       | 3 credits |
| <b>MTH 103</b>                              | Analytic Geometry             | 3 credits |
| <b>MTH 104</b>                              | Linear Algebra I              | 3 credits |
| <b>MTH 105</b>                              | Integral Calculus I           | 3 credits |
| <b>MTH 106</b>                              | Introduction to Number Theory | 3 credits |
| <b>MTH 150</b>                              | Math Lab I (MATHEMATICA)      | 3 credits |
| <b>MTH 199</b>                              | Viva Voce                     | 2 credits |
| <b>Non-Departmental Courses (8 Credits)</b> |                               |           |
| <b>PM 111</b>                               | Waves and Mechanics           | 2 credits |
| <b>PM 122</b>                               | Electricity and Magnetism     | 2 credits |
| <b>Stat M 101</b>                           | Introduction to Statistics    | 2 credits |
| <b>Stat M 102</b>                           | Introduction to Probability   | 2 credits |

**N. B.** Honours Students will collect the details syllabus of non-departmental courses from respective departments.

## List of Departmental & Non-Departmental Courses for Second Year

(33 Credits)

(Effective for 2023-2024 and onwards)

### Departmental Courses (29 Credits)

| Course No.                                  | Course Name                       | Credits   |
|---------------------------------------------|-----------------------------------|-----------|
| <b>MTH 201</b>                              | Real Analysis I                   | 3 credits |
| <b>MTH 202</b>                              | Differential Calculus II          | 3 credits |
| <b>MTH 203</b>                              | Ordinary Differential Equations I | 3 credits |
| <b>MTH 204</b>                              | Linear Algebra                    | 3 credits |
| <b>MTH 205</b>                              | Integral Calculus II              | 3 credits |
| <b>MTH 206</b>                              | Numerical Analysis I              | 3 credits |
| <b>MTH 207</b>                              | Discrete Mathematics              | 3 credits |
| <b>MTH 208</b>                              | Programming Fundamentals          | 3 credits |
| <b>MTH 250</b>                              | Math Lab II (MATLAB)              | 3 credits |
| <b>MTH 299</b>                              | Viva Voce                         | 2 credits |
| <b>Non-Departmental Courses (4 Credits)</b> |                                   |           |
| <b>Stat M 201</b>                           | Principles of Statistics          | 2 credits |
| <b>Stat M 202</b>                           | Mathematical Statistics I         | 2 credits |

**N. B.** Honours Students will collect the details syllabus of non-departmental courses from respective departments.

## **List of Departmental Courses for Third Year**

**(35 Credits)**

**(Effective for 2023-2024 and onwards)**

| <b>Course No.</b> | <b>Course Name</b>                    | <b>Credits</b> |
|-------------------|---------------------------------------|----------------|
| <b>MTH 301</b>    | Real Analysis II                      | 3 credits      |
| <b>MTH 302</b>    | Complex Analysis                      | 3 credits      |
| <b>MTH 303</b>    | Ordinary Differential Equations II    | 3 credits      |
| <b>MTH 304</b>    | Abstract Algebra                      | 3 credits      |
| <b>MTH 305</b>    | Fundamentals of Topology              | 3 credits      |
| <b>MTH 306</b>    | Numerical Analysis II                 | 3 credits      |
| <b>MTH 307</b>    | Mathematical Methods                  | 3 credits      |
| <b>MTH 308</b>    | Optimization                          | 3 credits      |
| <b>MTH 309</b>    | Stochastic calculus                   | 3 credits      |
| <b>MTH 310</b>    | Introduction to Actuarial Mathematics | 3 credits      |
| <b>MTH 350</b>    | Math Lab III (FORTRAN)                | 3 credits      |
| <b>MTH 399</b>    | Viva Voce                             | 2 credits      |

## List of Departmental Courses for Fourth Year

(35 Credits)

(Effective for 2023-2024 and onwards)

### MTH 401–MTH 406 (18 Credits)

| Course No.                                                                                                        | Course Name                               | Credits  |
|-------------------------------------------------------------------------------------------------------------------|-------------------------------------------|----------|
| <b>MTH 401</b>                                                                                                    | Introduction to Functional Analysis       | 3 credit |
| <b>MTH 402</b>                                                                                                    | Introduction to Measure Theory            | 3 credit |
| <b>MTH 403</b>                                                                                                    | Partial Differential Equations            | 3 credit |
| <b>MTH 404</b>                                                                                                    | Differential Geometry and Tensor Calculus | 3 credit |
| <b>MTH 405</b>                                                                                                    | Mechanics                                 | 3 credit |
| <b>MTH 406</b>                                                                                                    | Hydrodynamics and Fluid Dynamics          | 3 credit |
| <b>Courses MTH 411–MTH 420 to be offered by the Academic Committee (Three courses has to be taken: 9 Credits)</b> |                                           |          |
| <b>MTH 411</b>                                                                                                    | Combinatorics                             | 3 credit |
| <b>MTH 412</b>                                                                                                    | Fuzzy Mathematics                         | 3 credit |
| <b>MTH 413</b>                                                                                                    | Population Dynamics                       | 3 credit |
| <b>MTH 414</b>                                                                                                    | Scientific Computing and simulations      | 3 credit |
| <b>MTH 415</b>                                                                                                    | Introduction to Mathematical Finance      | 3 credit |
| <b>MTH 416</b>                                                                                                    | Stochastic Optimization                   | 3 credit |
| <b>MTH 420</b>                                                                                                    | Special Topics                            | 3 credit |
|                                                                                                                   |                                           |          |
| <b>MTH 450</b>                                                                                                    | Math Lab IV (MATLAB)                      | 3 credit |
| <b>MTH 490</b>                                                                                                    | Honours Project                           | 3 credit |
| <b>MTH 499</b>                                                                                                    | Viva Voce                                 | 2 credit |

**Total Credits: 134 (31+33+35+35)**

## **List of Non-Departmental Courses for 1<sup>st</sup> Year BS Honours Program**

### **Mathematics Courses for Honours Students of Departments other than Mathematics**

The minor courses in Mathematics is open to Honours students of other departments in the faculty of science. *Each student will pursue such courses as are required by her/his parent department.*

#### **First Year Minor Courses**

| <b>Course No.</b> | <b>Course Name</b>           | <b>Credits</b> |
|-------------------|------------------------------|----------------|
| <b>MTM 101</b>    | Fundamentals of Mathematics  | 2 credits      |
| <b>MTM 102</b>    | Calculus I                   | 2 credits      |
| <b>MTM 103</b>    | Analytic and Vector Geometry | 2 credits      |
| <b>MTM 104</b>    | Linear Algebra               | 2 credits      |
| <b>MTM 105</b>    | Calculus                     | 4 credits      |

## **List of Non-Departmental Courses for 2<sup>nd</sup> Year BS Honours Program**

### **Mathematics Courses for Honours Students of Departments other than Mathematics**

The minor courses in Mathematics are open to Honours students of other departments in the faculty of science. *Each student will pursue such courses as are required by her/his parent department.*

#### **Second Year Minor Courses**

| <b>Course No.</b> | <b>Course Name</b>              | <b>Credits</b> |
|-------------------|---------------------------------|----------------|
| <b>MTM 201</b>    | Mathematical Analysis           | 2 credits      |
| <b>MTM 202</b>    | Calculus II                     | 2 credits      |
| <b>MTM 203</b>    | Ordinary Differential Equations | 2 credits      |
| <b>MTM 204</b>    | Numerical Analysis              | 2 credits      |
| <b>MTM 205</b>    | Mathematical Methods            | 2 credits      |
| <b>MTM 206</b>    | Elementary Linear Algebra       | 2 credits      |

**Curriculum for Four-Year BS Honours Program**  
**Department of Mathematics**  
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**List of Departmental and Non-Departmental Courses for First Year**  
**(31 Credits)**  
**(Effective for 2023-2024 and onwards)**

**Departmental Courses (23 Credits)**

| Course No.                                  | Course Name                   | Credits   |
|---------------------------------------------|-------------------------------|-----------|
| <b>MTH 101</b>                              | Fundamentals of Mathematics   | 3 credits |
| <b>MTH 102</b>                              | Differential Calculus I       | 3 credits |
| <b>MTH 103</b>                              | Analytic Geometry             | 3 credits |
| <b>MTH 104</b>                              | Linear Algebra I              | 3 credits |
| <b>MTH 105</b>                              | Integral Calculus I           | 3 credits |
| <b>MTH 106</b>                              | Introduction to Number Theory | 3 credits |
| <b>MTH 150</b>                              | Math Lab I (MATHEMATICA)      | 3 credits |
| <b>MTH 199</b>                              | Viva Voce                     | 2 credits |
| <b>Non-Departmental Courses (8 Credits)</b> |                               |           |
| <b>PM 111</b>                               | Waves and Mechanics           | 2 credits |
| <b>PM 122</b>                               | Electricity and Magnetism     | 2 credits |
| <b>Stat M 101</b>                           | Introduction to Statistics    | 2 credits |
| <b>Stat M 102</b>                           | Introduction to Probability   | 2 credits |

**N. B.** Honours Students will collect the details syllabus of non-departmental courses from respective departments.

| MTH 101: Fundamentals of Mathematics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |                       |                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 101</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>Credit Hours:</b>    | <b>Year: First</b>    | <b>Semester:</b>         |
| <b>Course Title:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Fundamentals of Mathematics</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Theory</b>           |                       | <b>2023-2026</b>         |
| <b>Rationale:</b><br><br>Fundamentals of mathematics are the foundations of all mathematics courses the course is very productive. Understanding of this course will precede everyone to learn other areas of mathematics. After completion of this course, students will get some useful and applicable ideas on mathematical logic, methods of proofs, set theory, real and complex number system, inequality, relations and functions with graphs, equations, various types of series, and vectors.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                       |                          |
| <b>Course Objectives:</b><br><br><ol style="list-style-type: none"> <li>1. To give knowledge on some basic mathematical concepts.</li> <li>2. To provide brief idea about the use of mathematical logic, methods of proofs, set theory, real and complex number system and inequality.</li> <li>3. To give knowledge about the relations, functions in considerable detail.</li> <li>4. To provide details knowledge of polynomial and polynomial equations, algebraic and geometric series and vectors.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                         |                       |                          |
| <b>Course Contents:</b><br><br><ol style="list-style-type: none"> <li>1. <b>Elements of Logic:</b> Mathematical statements; Logical connectives; Conditional and biconditional statements; Truth tables and tautologies; Quantifications; Logical implication and equivalence; Deductive reasoning; Methods of proof (direct, indirect); method of induction.</li> <li>2. <b>Set Theory:</b> Sets and subsets; Set operations; Family of Sets; Cardinality of sets; De Morgan's laws; Applications of Set Theory.</li> <li>3. <b>Relations and Functions:</b> Cartesian product of sets; Relations; Order relation; Equivalence relations; Functions; Images and inverse images of sets.</li> <li>4. <b>Real Number System:</b> Field and order properties; Natural numbers, integers and rational numbers; Absolute value; Basic inequalities including inequalities involving means, powers; Inequalities of Weierstrass, Cauchy, Chebyshev.</li> <li>5. <b>Complex Number System:</b> Field of complex numbers; Geometrical representations; Polar form; De Moivre's theorem and its applications.</li> <li>6. <b>Summation of Finite Series:</b> Arithmetic and geometric series; Method of difference; Successive differences; Summation of trigonometric series.</li> <li>7. <b>Theory of Equations:</b> Synthetic division; Number of roots of polynomial equations; Relations between roots and coefficients; Sum of power of roots; Descartes rule of signs; number of real and imaginary roots; Multiplicity of roots; Symmetric functions of roots; Transformation of equations; Fundamental theorem of algebra (without proof).</li> <li>8. <b>Algebra of Vectors:</b> Scalar and vector products; Coplanar vectors; Scalar triple product; Vector triple product. Applications.</li> </ol> |                         |                       |                          |
| <b>Course Learning Outcomes (CLOs):</b><br><br>After the successful completion of the course, students will be able to:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                         |                       |                          |

- CLO1.** Explain the foundations of mathematics.
- CLO2.** Interpret the basic concepts of Logic.
- CLO3.** Evaluate equations and inequalities, both algebraically and graphically.
- CLO4.** Formulate the Weierstrass, Cauchy's and Chebycheff's inequalities.
- CLO5.** Calculate different mathematical problems of complex number.
- CLO6.** Distinguish among Arithmetic, Geometric and Harmonic Series.
- CLO7.** Interpret the ideas of the Summation of algebraic and trigonometric series.
- CLO8.** Calculate the different problems of Theory of equations.
- CLO9.** Identify the idea about De-Moivre's Theorem.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           |                                |      |      |      |      |      |      |       |       | x     |
| CLO8        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |
| CLO9        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                        | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1<br>CLO2                           | <b>Element of Logic</b>      | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3<br>CLO4                           | <b>Inequalities</b>          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5<br>CLO6                           | <b>Complex Number System</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                                   | <b>Summation of Series</b>   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8                                   | <b>Theory of Equations</b>   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO9                                   | <b>De-Moivre's Theorem</b>   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks.** Final Examination (Theory, 3 Hours): **70 Marks.**

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. S. Lipschutz, Set Theory, Schaum's Outline Series.
2. S. Barnard & J. M. Child, Higher Algebra.
3. P.R. Halmos, Naive Set Theory.
4. H. S. Hall and S. R. Knight, Higher Algebra.
5. Murray R Spiegel, Vector Analysis, Schaum's Outline Series.

**MTH 102: Differential Calculus I**

|                                |                         |                       |                          |
|--------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 102</b>    | <b>Credit Hours:</b>    | <b>Year: First</b>    | <b>Semester:</b>         |
| <b>Course Title:</b>           | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Differential Calculus I</b> | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>         | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

Calculus is one of the most fundamental courses in Mathematics which majorly contains two parts (Differential and Integral). The course Differential calculus I mainly contains the initial part of Differential calculus (Single variable function). Understanding this course will lead everyone to learn the other mathematical courses which needs the fundamentals of differentiation. After completing this course students will learn the basic idea of function, limits and continuity of functions, graphical representation of different functions, analysis of functions, basics of differentiation and the applications involving differentiation in different sectors of real life.

**Course Objectives:**

1. To develop the basic ideas of functions and their graphs.
2. To learn the ideas of limit and continuity of different functions in both mathematical and graphical way.
3. Understanding the techniques of differentiation and using them to solve the real life oriented problems.
4. Learning the basic properties of functions and analyze them both mathematically and graphically.
5. Understanding the ideas of infinite series involving differentiation.

**Course Contents:**

1. **Functions:** Concept of functions; Different types of functions (polynomial, rational, logarithmic, exponential, trigonometric, hyperbolic functions), inverses and graphs; transformation of graphs; Composite functions; Even, odd and symmetric functions; Application of functions.
2. **Limit and Continuity:** Limit of a function; Basic limit theorems with proofs; Limit at infinity and infinite limit; Sandwich (Squeezing) theorem; Continuous and discontinuous functions; Properties of continuous functions on closed and bounded intervals; Horizontal and vertical asymptotes; Intermediate Value Theorem.

3. **Differentiation:** Tangent lines and rates of change; Derivative of a function, One sided derivatives; Techniques of differentiation; Chain rule theorem; Successive differentiation; Leibnitz theorem; Rates of change in Natural and Social Sciences; Related rates; Marginal analysis and approximations with increments; Linear approximations and differentials; Indeterminate forms; L'Hospital's rules.
4. **Applications of Differentiation:** Concavity and extrema of functions; Curve sketching techniques; Rolle's theorem; Lagrange's and Cauchy's mean value theorems; Optimization problems; Newton's method; Applications to Business, Economics, Biology, Physics and Engineering sciences.
5. **Expansion of Functions:** Taylor's theorem with general form of the remainder; Lagrange's and Cauchy's forms of the remainder; Taylor's series; Maclaurin's series; Convergence of series and validity regions; Differentiation and integration of series; Validity of Taylor expansions and computation of series.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1:** Understand function both in mathematically and graphically.

**CLO2:** Understand the basic concepts of limit and continuity of function.

**CLO3:** Understand the basics of differentiation and techniques of differentiation.

**CLO4:** Understand some physical phenomena of differentiation.

**CLO5:** Solve some real life problems involving differentiation.

**CLO6:** Apply differentiation to analyze some properties of functions.

**CLO7:** Use differentiation to generate the idea of infinite series.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           |                                |      |      |      |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                       | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|-----------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                                   | <b>Functions</b>            | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                                   | <b>Limit and Continuity</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

|      |                                                                      |                                                                                        |                                                            |
|------|----------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO3 | <b>Differentiation</b>                                               | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4 | <b>Applications of Differentiation</b>                               | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5 | <b>Expansion of Functions</b>                                        | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6 | <b>Apply Differentiation to Analyze some Properties of Function.</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7 | <b>Use Differentiation to Generate the Idea of Infinite Series</b>   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. H. Anton, I. C. Bivens and S. Davis, Calculus: Early Transcendentals, Wiley.
2. E.W. Swokowski, Calculus with Analytic Geometry, Brooks/Cole.
3. G. B. Thomas and R. L. Finney, Calculus and Analytic Geometry.
4. J. Stewart, Calculus: Early Transcendentals.

| <b>MTH 103: Analytic Geometry</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                         |                       |                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 103</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Credit Hours:</b>    | <b>Year: First</b>    | <b>Semester:</b>         |
| <b>Course Title:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Analytic Geometry</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>Theory</b>           |                       | <b>2023-2026</b>         |
| <p><b>Rationale:</b></p> <p>Analytic Geometry is a branch of algebra that is used to model geometric objects- points, (straight) lines, and circles being the most basic of these. Analytic geometry is a great invention of Descartes and Fermat. Analytic geometry is used in physics and engineering, and also in aviation, rocketry, space science, and spaceflight. It is the foundation of most modern fields of geometry, including algebraic, differential, discrete and computational geometry. Usually the Cartesian coordinate system is applied to manipulate equations for planes, straight lines, and squares, often in two and sometimes three dimensions. Geometrically, one studies the Euclidean plane (two dimensions) and Euclidean space (three dimensions). The importance of analytic geometry is that it establishes a correspondence between geometric curves and algebraic equations. This correspondence makes it possible to reformulate problems in geometry as equivalent problems in algebra, and vice versa; the methods of either subject can then be used to solve problems in the other. For example, computers create animations for display in games and films by manipulating algebraic equations.</p> |                         |                       |                          |
| <p><b>Course Objectives:</b></p> <ol style="list-style-type: none"> <li>1. Determine the equation of a line from given information.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                         |                       |                          |

2. Determine the slope, x intercept, and y intercept of an equation, and use this information to graph the line.
3. Find the locus of points that are equidistant to two given points.
4. Find the locus of points that are a given distance away from a given point.
5. Find the locus where the line segment connecting each point with a given point is perpendicular to the line segment connecting with another given point.
6. Find the locus of points with problems dealing with points, slopes and multiplication of polynomials.
7. Find the coordinates of the focus and equation for the directrix of a parabola having the vertex at the origin and passing through a given point.
8. Find a Cartesian equation for the parabola with vertex at the origin, the axis given and a point on the parabola given. Use the definition of a parabola to find an equation for the parabola and given directrix.
9. Find an equation of an ellipse, graph and state the lengths of the major and minor axis when given the foci and vertices.
10. Find an equation of an ellipse when given its semi-major length (a) semi-minor length (b) and the principal axis. Find the coordinates of the vertices and foci of an ellipse when given an equation.
11. Find the center, vertices, foci, and endpoints of the conjugate axis, and the slope of the asymptotes of a hyperbola, and sketch the graph of the hyperbola.
12. Find the equation of a hyperbola from given information.
13. Find the coordinates of a point which divides the line segment joining two given points in a given ratio internally and externally.
14. Find the direction cosines and ratios of a line in space. Find the projection of a line segment on another line. Find the condition of perpendicularity and parallelism of two lines in space.
15. Students can develop geometry with a degree of confidence and will gain fluency in the basics of analytic geometry.

### **Course Contents:**

#### **Group A: Two-Dimensional Geometry**

1. **Coordinates in Two Dimensions:** Oblique and rectangular coordinate systems; Polar coordinates.
2. **Transformation of Coordinates:** Translation and rotation of axes; Transformed coordinates; Effect of translation and rotation on an equation.
3. **Standard Form of Second Degree Equation**
  - (a) **Pair of Straight Lines:** Existence and identification of pair of straight lines; Technique to compute pair of straight lines; Angle between two lines; Bisectors of angles between two lines; Homogeneous equation of second degree; Equation of pair of perpendicular straight lines to other pair.
  - (b) **Conic Sections:** Identification of conics using rotation of axes; Standard equations and properties of parabola, ellipse, and hyperbola; Tangent; Chord of contact; Pole and polar; Conjugate points and lines; Equation of chord in terms of its middle point; Pair of tangents; Reduction of equation of conics; Equations of conics in polar coordinates with applications; Parametric equations of conics.

### Group B: Three-Dimensional Geometry

4. **Coordinates in Three Dimensions:** Rectangular coordinates system in 3-space; Direction cosines and direction ratios; Projection of a line segment; Distance of a point from a line; Angle between two lines with given direction cosines and direction ratios.
5. **Plane in 3-Space:** Equations of planes; Co-planarity; Transformation of the general equation of a plane to the normal form; Angle between two intersecting planes; Plane parallel to a given plane; Length of perpendicular; Bisectors of the angles between two planes; Plane through the intersection of two planes;
6. **Line in 3-Space:** Symmetrical form of equation of a line; Equation of a line of intersection of two planes; Equation and shortest distance between two skew lines; Coplanar lines; Distance and angle between a straight line and a plane.
7. **Standard Forms of Conicoids:** Sphere, paraboloid, ellipsoid, hyperboloid (of one-sheet and two sheets) with sketches.

#### **Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Identify isometries like reflections, rotations and translations and use them to categorize conics. Define reflections, rotations and translations

**CLO2.** Apply these notions to curves. Use isometries to transform conics to canonic forms.

**CLO3.** Define conics and draw the graph of conics. Define circle, ellipse, hyperbola and parabola.

**CLO4.** Express equations of line in the space. Express equation of the line a point and direction of which are given.

**CLO5.** Describe equation of the line two points of which are given. Identify condition of perpendicular or parallel of two the lines.

**CLO6.** Express equation of the line that passes through a point and perpendicular to two lines. Express equations of planes in the space

**CLO7.** Express equation of the plane that passes through a point and perpendicular to the line given. Describe equation of the plane determined by three points.

**CLO8.** Express equation of the plane that passes through a point and is perpendicular to two directions. Solve many problems related to a line and plane in the space.

**CLO9.** Calculate distance from a point to a line, distance from a line to a line, distance from a point to a plane and define surfaces.

**CLO10.** Formulate equation of surfaces on Cartesian coordinates and locate any surface.

**CLO11.** Express intersection curve of two surfaces, explain a sphere and express a cylinder.

**CLO12.** Define ellipsoid and express hyperboloid of one and two sheets.

#### **Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |

|       |   |  |   |  |  |  |   |  |  |  |  |   |
|-------|---|--|---|--|--|--|---|--|--|--|--|---|
| CLO7  | x |  |   |  |  |  |   |  |  |  |  | x |
| CLO8  | x |  |   |  |  |  | x |  |  |  |  | x |
| CLO9  | x |  |   |  |  |  | x |  |  |  |  | x |
| CLO10 | x |  | x |  |  |  |   |  |  |  |  | x |
| CLO11 | x |  | x |  |  |  |   |  |  |  |  | x |
| CLO12 | x |  | x |  |  |  |   |  |  |  |  | x |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                          | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1<br>CLO2                  | <b>Coordinates in Two Dimensions</b>           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3<br>CLO4                  | <b>Transformation of Coordinates</b>           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5<br>CLO6                  | <b>Standard form of Second Degree Equation</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                          | <b>Coordinates in Three Dimensions</b>         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8<br>CLO9                  | <b>Plane in 3-Spaces</b>                       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO10<br>CLO11                | <b>Line in 3-Space</b>                         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO12                         | <b>Standard Forms of Conicoids</b>             | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which answer any **Five (05)** questions and taking at least **Two (02)** questions from each group.

**References:**

1. H. Anton, I. C. Bivens and S. Davis, Calculus: Early Transcendental, Wiley.
2. E.W. Swokowski, Calculus with Analytic Geometry, Brooks/Cole; Alternate.
3. Khosh Mohammad, Analytic Geometry and Vector Analysis.
4. J. A. Hummel, Vector Geometry.
5. S. Lang, A First Course in Calculus.

| MTH 104: Linear Algebra I                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                         |                       |                                              |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------|----------------------------------------------|
| <b>Course Code: MTH 104</b><br><b>Course Title:</b><br><b>Linear Algebra I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>Credit Hours:</b><br><b>3.00 Hrs/Week</b><br><b>Total Marks: 100</b> | <b>Year: First</b>    | <b>Semester:</b>                             |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>Course Type:</b><br><b>Theory</b>                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br><b>2023-2026</b> |
| <p><b>Rationale:</b></p> <p>Linear algebra is an essential part of the curriculum of majors such as: Computer science, Engineering, Economics, Physics, and Mathematics. It has a broad range of applications in those areas. For most students, Linear Algebra is the first course that blends computational and conceptual aspects of mathematics. The study of linear algebra is motivated by the geometry of problems in two and three dimensions. A clear understanding of the concepts of linear algebra is essential for the proper description and representation of all physical and mathematical phenomena in higher dimensions. The algorithms of linear algebra are also central to the theory of scientific computing and numerical analysis.</p> <p>A first course in linear algebra serves as an introduction to the development of logical structure, deductive reasoning and mathematics as a language. For students, the tools developed from a course in linear algebra will be as fundamental in their professional work as the basic tools of calculus. For these reasons, this course is a core course for students pursuing a major in mathematics.</p>                                                                                                                                                                           |                                                                         |                       |                                              |
| <p><b>Course Objectives:</b></p> <ol style="list-style-type: none"> <li>1. Work with the basic arithmetic operations on vectors and matrices, including inversion, using technology where appropriate.</li> <li>2. Perform row operations and find echelon forms.</li> <li>3. Learn to solve systems of linear equations and application problems requiring them.</li> <li>4. Learn to compute determinants and know their properties.</li> <li>5. Learn about and work with vector spaces and subspaces.</li> <li>6. Learn about and work with linear transformations.</li> <li>7. Learn to the basic terminology of linear algebra in Euclidean spaces, including linear independence, spanning, basis, rank, nullity.</li> <li>8. Learn to find and use eigenvalues and eigenvectors of a matrix.</li> <li>9. Learn about inner products and their uses.</li> <li>10. Understand the axiomatic structure of a modern mathematical subject and learn to construct simple proofs.</li> <li>11. Learn to the common applications of Linear Algebra, possibly including Markov chains, areas and volumes, Cramer's rule, the adjoint, and the method of least squares.</li> <li>12. Use mathematically correct language and notation for Linear Algebra.</li> <li>13. Become computational proficiency involving procedures in Linear Algebra.</li> </ol> |                                                                         |                       |                                              |
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li>1. <b>System of Linear Equations and Matrices:</b> System of linear equations; Elementary row operations; Gaussian elimination; Algebra on Matrices; Invertible matrices; Determinant and its properties; Applications to Leontief input-output Economic models, Markov chains, Computer graphics, Network Flow and Electrical Networks, Balancing chemical equations.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                         |                       |                                              |

2. **Euclidean Vector Spaces:** Vectors in  $\mathbb{R}^n$ , Inner product. Norm and distance; Orthogonality.
3. **General Vector Spaces:** Vector space; Subspace; Linear dependence of vectors; basis and dimension of vector spaces; Change of bases; Row space and Column space of a matrix; rank of matrices; Solution spaces of systems of linear equations; Application to Polynomials.
4. **Linear Transformations:** Matrix transformations; Linear transformations; Examples and illustrations with applications; Kernel and image of a linear transformation and their properties.
5. **Eigenvalues and Eigenvectors of Matrices:** Eigenvalues and eigenvectors; Diagonalization; Cayley-Hamilton theorem; Complex Vector Spaces; Application to Least square approximation.

#### **Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Solve systems of linear equations and homogeneous systems of linear equations by Gaussian elimination and Gauss-Jordan elimination.

**CLO2.** Row-reduce a matrix to either row-echelon or reduced row-echelon form.

**CLO3.** Use matrix operations to solve systems of equations and be able to determine the nature of the solutions.

**CLO4.** Understand some applications of systems of linear equations.

**CLO5.** Perform operations with matrices and find the transpose and inverse of a matrix.

**CLO6.** Calculate determinants using row operations, column operations and expansion down any column and across any row.

**CLO7.** Interpret vectors in two and three-dimensional space both algebraically and geometrically.

**CLO8.** Recognize the concepts of the terms span, linear independence, basis, and dimension, and apply these concepts to various vector spaces and subspaces,

**CLO9.** Find the kernel, range, rank, and nullity of a linear transformation.

**CLO10.** Calculate Eigenvalues and their corresponding eigenspaces.

**CLO11.** Understand the concept of a linear transformation as a mapping from one vector space to another and be able to calculate its matrix representation with respect to standard and nonstandard bases.

**CLO12.** Determine if a matrix is diagonalizable, and if it is, how to diagonalize it.

#### **Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              | x    | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              | x    |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              | x    |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              | x    |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              | x    |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              | x    |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           | x                              | x    |      |      |      |      |      |       |       | x     |
| CLO8        | x               |           | x                              | x    |      |      | x    |      |      |       |       | x     |
| CLO9        | x               |           | x                              | x    |      |      | x    |      |      |       |       | x     |

|       |   |  |   |   |  |  |   |  |  |  |  |   |
|-------|---|--|---|---|--|--|---|--|--|--|--|---|
| CLO10 | x |  | x | x |  |  | x |  |  |  |  | x |
| CLO11 | x |  | x | x |  |  | x |  |  |  |  | x |
| CLO12 | x |  | x | x |  |  |   |  |  |  |  | x |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                                                     | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1<br>CLO2                  | <b>Matrices And Determinants</b>                                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3<br>CLO4                  | <b>System of Linear Equations</b>                                         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5<br>CLO6                  | <b>Vectors in <math>\mathbb{R}^n</math> and <math>\mathbb{C}^n</math></b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7<br>CLO8                  | <b>Vector Spaces</b>                                                      | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO9<br>CLO10                 | <b>Linear Transformations</b>                                             | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO11<br>CLO12                | <b>Eigenvalues and Eigenvectors of Matrices</b>                           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. H. Anton, and C. Rorres, Linear Algebra with Applications, 10th Edition.
2. S. Lipschutz, Linear Algebra, Schaum's Outline Series.
3. David C. Lay, Linear Algebra and its Applications, 4th Edition.
4. W. K. Nicholson, Linear Algebra with Applications, 3th Edition.
5. B. Kolman & D. R. Hill, Elementary Linear Algebra with Applications, 9th Edition.

| MTH 105: Integral Calculus I |                         |                       |                          |
|------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 105</b>  | <b>Credit Hours:</b>    | <b>Year: First</b>    | <b>Semester:</b>         |
| <b>Course Title:</b>         | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Integral Calculus I</b>   | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>       | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                              | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

In mathematics, an integral assigns numbers to functions in a way that describes displacement, area, volume, and other concepts that arise by combining infinitesimal data. The process of finding integrals is called integration. Along with differentiation, integration is a fundamental

operation of calculus, and serves as a tool to solve problems in mathematics and physics involving the area of an arbitrary shape, the length of a curve, and the volume of a solid, among others.

**Course Objectives:**

1. To perform integration and other operations for certain types of functions and carry out the computation fluently.
2. Approximation techniques for integration.
3. To determine whether a sequence or a series is convergent or divergent and evaluate the limit of a convergent sequence or the sum of a convergent series.
4. To recognize when and explain why such operations are possible and/or required.
5. To interpret results and determine if the solutions are reasonable. In addition, students will apply the above skills and knowledge to translate a practical problem involving some real-life applications into mathematical problem and solve it by mean of Calculus. The applications include science and engineering problems involving areas, volumes, average values, kinematics, work, hydrostatic forces, centroid, and separable differential equations. Students will also learn simple concepts involving sequences, series and power series.

**Course Contents:**

1. **Various Techniques of Integration:** Antiderivatives and indefinite integrals; Techniques of integration; Definite integration using antiderivatives; Definite integration using Riemann sums.
2. **Properties of Integration:** Basic properties; Fundamental theorems of calculus; Mean Value Theorem for integrals; Integration by reduction; Walli's formulae with geometrical interpretation.
3. **Applications of Integration:** Areas; Volumes of solid by slicing, disks and washers; Volumes by cylindrical shells; Average value of a function; Arc length; Area of a surface of revolution; Applications to Business, Economics, Social Sciences, Biology and Engineering sciences.
4. **Improper Integrals:** Different types of improper integrals; Test for convergence (comparison, ratio, absolute and conditional); Application to probability distribution; Gamma and beta functions.
5. **Parametric and Polar Curves:** Arc length for parametric curves; Graphing in polar equations; Tangent lines, arc length and area for Polar Curves; Area and volume of surface by revolving in Polar coordinates.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Compute integrals of basic functions by using antiderivative formulas and techniques such as substitution, integration by parts, trigonometric identities, trigonometric substitutions, partial fraction decomposition and rationalizing substitutions. Be able to simplify and manipulate the integrand and choose an effective technique or combination of techniques based on the form of the integrand.

**CLO2.** Compute definite integrals by using the fundamental theorem of calculus. Be able to recognize functions that are given as definite integrals with variable upper and lower limits and

find their derivatives, relate antiderivatives to definite and indefinite integrals, and the net change as the definite integral of a rate of change.

**CLO3.** Approximate the area between a curve and the x-axis by using the left, right or midpoint sums. Interpret a definite integral in terms of the area between a curve and the x-axis. Compute definite integrals by using the Riemann sum, the definition of a definite integral. Use the comparison properties to estimate the value of a definite integral.

**CLO4.** Construct an integral or a sum of integrals that can be used to find the volume of a solid by considering its cross-sectional areas. For solids that are obtained by revolving a region about an axis of rotation, find the volume by considering cross-sectional discs or washers.

**CLO5.** Determine whether an improper integral (which either has infinite lower or upper limits of integration, or has a integrand with infinite discontinuities within or at the boundary of the interval of integration) diverges or converges, by evaluating the improper integral or by using the comparison theorem.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                              | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                                   | <b>Introduction</b>                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                                   | <b>Properties of Integration</b>   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                                   | <b>Applications of Integration</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                                   | <b>Improper Integrals</b>          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                                   | <b>Parametric and Polar Curves</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. H. Anton, I. C. Bivens and S. Davis, Calculus: Early Transcendentals, Wiley.
2. E.W. Swokowski, Calculus with Analytic Geometry, Brooks/Cole.
3. G. B. Thomas and R. L. Finney, Calculus and Analytic Geometry.
4. J. Stewart, Single Variable Calculus: Early Transcendentals.
5. R. Larson, R. P. Hostetler, F. H. Edwards and D. E. Heyd, Calculus with Analytic Geometry, Houghton Mifflin College Div.

**MTH 106: Introduction to Number Theory**

|                                      |                         |                       |                          |
|--------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 106</b>          | <b>Credit Hours:</b>    | <b>Year: First</b>    | <b>Semester:</b>         |
| <b>Course Title:</b>                 | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Introduction to Number Theory</b> | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>               | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                      | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

Elementary Number Theory is the study of the basic structure and properties of natural numbers. Learning Number Theory helps improving one's ability of mathematical thinking. After completion of this course, students will prove results involving divisibility and greatest common divisors; solve systems of linear congruence's; find integral solutions to specified linear Diophantine Equations; apply Euler-Fermat's Theorem to prove relations involving prime numbers; apply the Wilson's theorem.

**Course Objectives:**

1. Identify and apply various properties of and relating to the natural numbers including the well-ordering principle, primes, unique factorization, the division algorithm, and greatest common divisors.
2. Identify certain number theoretic functions and their properties.
3. Understand the concept of congruences and use various results related to congruences including the Chinese Remainder Theorem.
4. Solve certain types of Diophantine equations.

**Course Contents:**

1. **Divisibility:** Definition; properties; division algorithm; greatest integer function.
2. **Primes:** Definition, Euclid's Theorem; Prime Number Theorem (statement only); Goldbach and Twin Primes conjectures; Fermat primes; Fermat's Theorem; Mersenne primes.
3. **Prime Factorizations:** Definition and properties of greatest common divisor (GCD) and least common multiple (LCM); Euclid's algorithm; Fundamental Theorem of Arithmetic; Linear Diophantine equations; Continued Fractions; Euclid's Lemma; Canonical prime factorization; divisibility; GCD; and LCM in terms of prime factorizations.
4. **Congruences:** Definitions and basic properties; residue classes; complete residue systems; reduced residue systems; Linear congruences in one variable; Euclid's algorithm; Simultaneous linear congruences; Chinese Remainder Theorem; Wilson's

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|-----------|--------------------------------|----------------------------------------------------------------------------------------|------|------|------|------|------------------------------------------------------------|-------|-------|-------|
| Theorem; Euler's Theorem; Pseudoprimes and Carmichael; Application of congruences (Divisibility test, Round robin tournaments, ISBN Check Digits).                                                                                                                                                                                                                                                                                                                                               |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| 5. <b>Arithmetic Functions:</b> Arithmetic function and Multiplicative functions (definitions and basic examples); The Moebius function; The Euler phi function; Carmichael conjecture; Number of divisors and sum of divisors functions; Perfect numbers; Characterization of even perfect numbers, Representation of numbers by sum of two and four squares; Application of Number theory in Cryptography; Encryption Schemes, Ceaser cipher algorithm, Rivest-Shamir-Adleman (RSA) Algorithm. |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>Course Learning Outcomes (CLOs):</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| After the successful completion of the course, students will be able to:                                                                                                                                                                                                                                                                                                                                                                                                                         |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>CLO1.</b> Effectively express the concepts and results of Number Theory.                                                                                                                                                                                                                                                                                                                                                                                                                      |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>CLO2.</b> Understand the logic and methods behind the major theorems and their proofs in Number Theory.                                                                                                                                                                                                                                                                                                                                                                                       |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>CLO3.</b> Construct mathematical proofs of statements and look for counter examples to establish falsity of some the statements.                                                                                                                                                                                                                                                                                                                                                              |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>CLO4.</b> Understand and verify the conjectures about the natural numbers.                                                                                                                                                                                                                                                                                                                                                                                                                    |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>CLO5.</b> Use concepts of number theory to solve huge number of real life problems.                                                                                                                                                                                                                                                                                                                                                                                                           |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>Mapping of CLOs with PLOs:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO/<br>PLO                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | PLO1<br>(Funda)                   | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4                                                                                   | PLO5 | PLO6 | PLO7 | PLO8 | PLO9                                                       | PLO10 | PLO11 | PLO12 |
| CLO1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | x                                 |           | x                              |                                                                                        | x    | x    | x    | x    | x                                                          | x     | x     | x     |
| CLO2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | x                                 |           | x                              |                                                                                        |      |      |      |      | x                                                          |       |       | x     |
| CLO3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | x                                 |           | x                              |                                                                                        |      |      |      |      |                                                            |       |       | x     |
| CLO4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | x                                 |           | x                              |                                                                                        |      |      |      |      |                                                            |       |       | x     |
| CLO5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | x                                 |           | x                              |                                                                                        |      | x    |      |      |                                                            |       |       | x     |
| <b>Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning &amp; Assessment Strategy:</b>                                                                                                                                                                                                                                                                                                                                                                                             |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| Course Learning Outcome (CLO)                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Topic                             |           |                                | Teaching-Learning Strategies                                                           |      |      |      |      | Assessment Strategies                                      |       |       |       |
| CLO1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Divisibility                      |           |                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Primes                            |           |                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Fundamental Theorem of Arithmetic |           |                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Congruences                       |           |                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Arithmetic Functions              |           |                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| <b>Evaluation:</b> In-course Assessment: <b>30 Marks</b> . Final Examination (Theory, 3 Hours): <b>70 Marks</b> .                                                                                                                                                                                                                                                                                                                                                                                |                                   |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. S. G Telang, Number Theory.
2. James Strayer, Elementary Number Theory.
3. G H. Hardy and E. M. Wright, An Introduction to Theory of Number.
4. Kenneth Rosen, Elementary Number Theory and its Applications.
5. Fatema Chowdhury and Munibur Rahman Choudhury, Essentials of Number Theory.

**MTH 150: Math Lab I (MATHEMATICA)**

|                                 |                         |                       |                          |
|---------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 150</b>     | <b>Credit Hours:</b>    | <b>Year: First</b>    | <b>Semester:</b>         |
| <b>Course Title:</b>            | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Math Lab I (MATHEMATICA)</b> | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>          | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                 | <b>Lab</b>              |                       | <b>2023-2026</b>         |

**Rationale:**

MATHEMATICA is a robust tool for professionals and researchers who require advanced mathematical capabilities and are willing to invest in a comprehensive software solution. However, its cost, learning curve, and resource requirements may make it less suitable for casual users or those with simpler needs. MATHEMATICA uses controlled high-precision numbers and symbolic analysis to solve problems that are intractable with traditional numerical methods and limited-precision numbers.

**Course Objectives:**

1. develop creativity and the ability to think, communicate, and solve problems.
2. develop number and spatial sense and the ability to appreciate patterns and structures of number and shapes.
3. Enhance students' lifelong learning abilities through basic mathematical knowledge.

**Course Contents:**

1. Problems Solving: Problems in the courses of First Year BS Honours will be solved using Computer Algebra System (CAS) MATHEMATICA.
2. Lab Assessment: Take Class Test.
3. Lab Assignments: Course instructors will provide a list of Lab assignments.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

- CLO1.** Understanding MATHEMATICA/ MATLAB/ FORTRAN/ C/ Mapple.  
**CLO2.** Apply any of the programming language in higher study.  
**CLO3.** Solve real life problem using the programming language.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                   | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|-------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | <b>Problems Solving</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | <b>Lab Assessment</b>   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | <b>Lab Assignments</b>  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** Internal Assessment: **40 Marks**, Final Examination (Lab 3 Hours): **60 Marks**.

**Four (04)** questions of equal value will be set, of which **All Questions** are to be answered.

**References:**

1. Hands-on Start to Wolfram Mathematica and Programming with the Wolfram Language by Cliff Hastings, Kelvin Mischo, Michael Morrison, 2016.
2. Mathematica: A Secret World of Intuition and Curiosity by David Bessis, Translated by Kevin Frey.
3. Introduction to Mathematica, Springer Computational Geoscience with Matematica.
4. Programming with Mathematica: An Introduction By Paul Wellin.
5. Schaum's Outline of Mathematica and the Wolfram Language, Third Edition (Schaum's Outlines).

**MTH 199: Viva Voce**

**Credits: 2**

**Viva Voce on courses taught in the First Year.**

**Curriculum for Four-Year BS Honours Program**  
**Department of Mathematics**  
**University of Dhaka**



**List of Departmental and Non-Departmental Courses for Second Year**  
**(33 Credits)**  
**(Effective for 2023-2024 and onwards)**

**Departmental Courses (29 Credits)**

| Course No.                                  | Course Name                       | Credits   |
|---------------------------------------------|-----------------------------------|-----------|
| <b>MTH 201</b>                              | Real Analysis I                   | 3 credits |
| <b>MTH 202</b>                              | Differential Calculus II          | 3 credits |
| <b>MTH 203</b>                              | Ordinary Differential Equations I | 3 credits |
| <b>MTH 204</b>                              | Linear Algebra II                 | 3 credits |
| <b>MTH 205</b>                              | Integral Calculus II              | 3 credits |
| <b>MTH 206</b>                              | Numerical Analysis I              | 3 credits |
| <b>MTH 207</b>                              | Discrete Mathematics              | 3 credits |
| <b>MTH 208</b>                              | Programming Fundamentals          | 3 credits |
| <b>MTH 250</b>                              | Math Lab II (MATLAB)              | 3 credits |
| <b>MTH 299</b>                              | Viva Voce                         | 2 credits |
| <b>Non-Departmental Courses (4 Credits)</b> |                                   |           |
| <b>Stat M 201</b>                           | Principles of Statistics          | 2 credits |
| <b>Stat M 202</b>                           | Mathematical Statistics I         | 2 credits |

**N. B.** Honours Students will collect the details syllabus of non-departmental courses from respective departments.

| MTH 201: Real Analysis I                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                         |                       |                                              |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------|----------------------------------------------|
| <b>Course Code: MTH 201</b><br><b>Course Title:</b><br><b>Real Analysis I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Credit Hours:</b><br><b>3.00 Hrs/Week</b><br><b>Total Marks: 100</b> | <b>Year: Second</b>   | <b>Semester:</b>                             |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>Course Type:</b><br><b>Theory</b>                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br><b>2023-2026</b> |
| <p><b>Rationale:</b></p> <p>As the functions of real variable models natural events, it is important to understand the properties of a function of a real variable. This course gives a proper treatment in understanding of the real number set which facilitates the subsequent properties of a function beyond the informal treatment of objects in calculus.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                         |                       |                                              |
| <p><b>Course Objectives:</b></p> <p>After an elaborate introduction of calculus, in higher secondary and first year honors class, mostly in computations and heuristic intuitive arguments, we would like students to get engaged in alluring complex structure of the real number set, fineness of convergence of limit and series, stimulating paradoxical mirages in infinite. To expose the students to a level of understanding the short comings of informal treatment in dealing with objects in calculus, and the need of schematic rigorous study, and to practice writing formal mathematical proof.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                         |                       |                                              |
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li><b>1. Real Numbers:</b> Bounded sets of real numbers. Supremum and infimum. The completeness axiom and its consequences. Dedekind's theorems. Cluster (limit) points; Bolzano-Weierstrass theorem.</li> <li><b>2. Sequence and Series:</b> Infinite sequences. Convergence. Theorems on limits. Monotone sequences, subsequences. Cauchy's general principle of convergence. Cauchy's first and second theorems on limits, Infinite series of real numbers, convergence and absolute convergence. Tests for convergence; Gauss's tests (simplified form). Alternating series (Leibnitz's test). Product of infinite series.</li> <li><b>3. Continuity:</b> Properties of continuous functions. Intermediate value theorem.</li> <li><b>4. Differentiation:</b> Derivatives and its properties, Mean Value theorem, Taylor's theorem, Darboux's theorem.</li> <li><b>5. Integration:</b> The Riemann Stieltjes integral; definitions via Riemann's sums and Darboux's sums. Darboux's theorem. Necessary and sufficient conditions for integrability. Classes of integrable functions. Fundamental theorems of calculus.</li> </ol> |                                                                         |                       |                                              |
| <p><b>Course Learning Outcomes (CLOs):</b></p> <p>After the successful completion of the course, students will be able to:</p> <p><b>CLO1.</b> understand foundations of Number System.</p> <p><b>CLO2.</b> understand different properties of open sets and closed sets.</p> <p><b>CLO3.</b> learn the structure of the set of real numbers from the consequences of axiom of completeness.</p> <p><b>CLO4.</b> write formal proofs of different theories using logic in mathematical analysis.</p> <p><b>CLO5.</b> understand concept of limit, ideas of convergence of real sequence and series.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                         |                       |                                              |

**CLO6.** Test the convergence of series.  
**CLO7.** rigorously understand continuity, differentiability of real valued function.  
**CLO8.** Learn Riemann integrability of a real function and their properties.  
**CLO9.** Understand relation between Darboux integral and Riemann integral.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              | x    | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              | x    | x    |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              | x    | x    |      |      |      | x    |       |       | x     |
| CLO4        | x               |           | x                              | x    | x    |      |      |      | x    |       |       | x     |
| CLO5        | x               |           | x                              | x    | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO6        | x               |           | x                              | x    |      |      |      |      | x    |       |       | x     |
| CLO7        | x               |           | x                              | x    |      |      |      |      | x    |       |       | x     |
| CLO8        | x               |           | x                              | x    |      |      |      |      | x    |       |       | x     |
| CLO9        | x               |           | x                              | x    |      |      |      |      | x    |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                                                            | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1<br>CLO2                           | <b>Bounded sets of Real Numbers, Open Sets, Closed Sets and their Properties</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3<br>CLO4                           | <b>Completeness Axiom and consequence</b>                                        | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                                   | <b>Infinite Sequences</b>                                                        | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                                   | <b>Infinite Series</b>                                                           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                                   | <b>Continuous Functions and their Derivatives</b>                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8<br>CLO9                           | <b>The Riemann Integral and Darboux's Integral</b>                               | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. Stephen Abbott, Understanding Analysis.
2. K. A. Ross, Elementary Analysis: The Theory of Calculus.
3. R. G. Bartle, & D. R. Sherbert, Introduction to Real Analysis.
4. W. Rudin, Principles of Mathematical Analysis.

| MTH 202: Differential Calculus II                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                         |                       |                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 202</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>Credit Hours:</b>    | <b>Year: Second</b>   | <b>Semester:</b>         |
| <b>Course Title:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Differential Calculus II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>Theory</b>           |                       | <b>2023-2026</b>         |
| <p><b>Rationale:</b></p> <p>Calculus, the branch of mathematics concerned with the calculation of instantaneous rates of change (differential calculus) and the summation of infinitely many small factors to determine some whole (integral calculus). Calculus is considered to be one of the greatest achievements of the human intellect and it is now the basic entry point for anyone wishing to study physics, chemistry, biology, economics, finance, or actuarial science. The development of calculus in the seventeenth and eighteenth centuries was motivated by the need to understand physical phenomena such as the tides, the phases of the moon, the nature of light, gravity etc.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                       |                          |
| <p><b>Course Objectives:</b></p> <p>This course is designed to introduce the students to the advanced topics of Calculus and Analytic Geometry. This course will help the students to understand basic facts and terminology relating to functions of several variables, partial derivatives and directional derivatives. The students will be able to visualize the algebraic equations as geometric curves and conversely to present geometric curves by algebraic equations. This course will also enable the students to understand the Vector-valued functions of a single variable their Limits continuity and differentiability.</p> <p>The students will also be able to learn Tangent lines to graphs of vector-valued functions, Arc length from vector viewpoint, and Arc length parametrization. Finally, the students will know how to apply this knowledge in real life problems.</p>                                                                                                                                                                                                                                      |                         |                       |                          |
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li><b>1. Vector-Valued Functions of a Single Variable:</b> Limits, derivatives of vector valued functions.</li> <li><b>2. Tangent Lines and Arc Length:</b> Tangent lines to graphs of vector-valued functions; Arc length from vector view point; Arc length parametrization.</li> <li><b>3. Curvature of Plane and Space Curves:</b> Curvature of intrinsic equations, Cartesian and parametric equations; Radius of curvature and Centre of curvature.</li> <li><b>4. Partial Differentiation:</b> Functions of several variables; Graphs of functions of two variables; Limits and continuity; Partial derivatives; Differentiability; Linearization and differentials; The Chain rule; Partial derivatives with constrained variables; Directional derivatives; gradient vectors and tangent planes.</li> <li><b>5. Extrema of Multi-Variable Functions:</b> Taylor's series; Extrema of functions of several variables; Lagrange multipliers.</li> <li><b>6. Differentiation of Vectors:</b> Gradient, Divergence, Curl and their physical meanings.</li> </ol> |                         |                       |                          |
| <p><b>Course Learning Outcomes (CLOs):</b></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                         |                       |                          |

After the successful completion of the course, students will be able to:

**CLO1.** Develop a clear understanding of the fundamental concepts of vector calculus and partial derivatives.

**CLO2.** Solve various problems using the basic concepts of vector calculus.

**CLO3.** Visualize graphs of curve in 3D, surface and analyze various properties of them.

**CLO4.** Apply ideas of partial derivatives in many real-life problems

**CLO5.** Find extreme values of multivariable functions using different approaches and apply them to solve practical problems.

**CLO6.** Develop a clear idea of physical significance of gradient, divergence and curl and learn some physical applications of them.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | X               | X         | X                              |      | X    |      |      |      |      |       |       |       |
| CLO2        | X               | X         | X                              |      | X    |      |      |      |      | X     |       |       |
| CLO3        | X               | X         | X                              | X    | X    | X    |      |      |      |       |       | X     |
| CLO4        | X               | X         | X                              | X    |      | X    | X    |      | X    |       |       |       |
| CLO5        | X               | X         | X                              | X    |      | X    | X    |      | X    |       |       |       |
| CLO6        | X               | X         | X                              | X    |      | X    | X    |      | X    |       |       |       |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                                                                                             | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|-------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1<br>CLO2                           | Vector-valued functions of a single variable                                                                      | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO1<br>CLO2                           | Tangent lines to graphs of vector-valued functions. Arc length from vector viewpoint. Arc length parametrization. | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO1<br>CLO2                           | Curvature of plane and space curves:                                                                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO1<br>CLO3<br>CLO4                   | Partial Differentiation                                                                                           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4<br>CLO5                           | Extrema of functions of several variables                                                                         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO1<br>CLO2<br>CLO6                   | Differentiation of Vectors, Gradient, Divergence and curl                                                         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. H. Anton, I.C. Bivens and S. Davis, Calculus: Early Transcendentals, Wiley (10th Edition).
2. E.W. Swokowski, Calculus with Analytic Geometry, Brooks/Cole.
3. G.B. Thomas and R. L. Finney, Calculus and Analytic Geometry, Addison Wesley.
4. J. Stewart, Multi Variable Calculus: Early Transcendentals, Cengage Learning.
5. R. Larson, R. P. Hostetler, F. H. Edwards and D. E. Heyd, Calculus with Analytic Geometry, Houghton Mifflin College Div.

**MTH 203: Ordinary Differential Equations I**

|                                          |                         |                       |                          |
|------------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 203</b>              | <b>Credit Hours:</b>    | <b>Year: Second</b>   | <b>Semester:</b>         |
| <b>Course Title:</b>                     | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Ordinary Differential Equations I</b> | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>                   | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                          | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

The construction of mathematical models to address real life problems has been one of the most important aspects of each of the branches of science. These mathematical models are formulated in terms of equations involving functions and their derivatives. Such equations are called differential equations. If only one independent variable is involved, often time, the equations are called ordinary differential equations. Ordinary differential equations (ODEs) are a fundamental part of the mathematical vocabulary used to describe natural phenomena. The course emphasizes classical methods for finding exact solution formulas. After completion of this course, the students will get some useful and applicable ideas for modeling physical and other phenomena.

**Course Objectives:**

1. Derive a basic first-order ODE model from a description of a physical system.
2. Understand the concepts of initial value problem and solution.
3. Learn to identify the type of a given differential equation and select and apply the appropriate analytical technique for finding the solution of first order and selected higher order ordinary differential equations.
4. Learn to solve differential equations with constant and variable coefficients.
5. Learn to solve real-world problems in fields such as Biology, Chemistry, Economics, Engineering, and Physics modeled by first and second order differential equations.
6. Gather experience to solve system of equations with constant coefficients.

**Course Contents:**

1. **Ordinary Differential Equations and Their Solutions:** Classification of differential equations. Solutions. Implicit solutions. Singular solutions. Initial and Boundary value problems. Basic existence and uniqueness theorems (statement and illustration only). Direction fields and Phase plane.
2. **First Order Differential Equations with Modelling Applications:** Separable equations. Linear equations, Exact equations, Integrating factors, Substitutions and transformations. Construction of differential equations as mathematical models

(exponential growth and decay, heating and cooling, mixture of solutions, series circuit, logistic growth, chemical reaction, falling bodies). Model solutions and interpretation of results. Orthogonal and oblique trajectories.

3. **Higher Order Linear Differential Equations with Modelling Applications:** Linear differential operators. Basic theory of linear differential equations. Solution space of homogeneous linear equations. Fundamental solutions of homogeneous equations. Reduction of order. Homogeneous and Non-homogeneous linear equations with constant coefficients. Method of undetermined coefficients and variation of parameters. Inverse operators. Cauchy-Euler differential equations. Mathematical models (Vibration of a mass on a spring, free and undamped motion; free and damped motion; forced motion; resonance phenomena; electric circuit problems, motion of a rocket).
4. **Systems of Linear First Order Differential Equations:** Elimination method. Matrix method for homogeneous linear systems with constant coefficients. Variation of parameters. Matrix exponential.

#### **Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Identify/classify differential equations by order, linearity, and homogeneity

**CLO2.** Solve first/higher order linear differential equations with and without initial conditions

**CLO3.** Determine regions of the plane over which a given order differential equation will have a unique solution

**CLO4.** Prepare for success in disciplines which rely on differential equations.

**CLO5.** Analyze real-world problems (in fields such as Biology, Chemistry, Economics, Engineering, and Physics, including problems related to population dynamics, mixtures, growth and decay, heating and cooling, electronic circuits, and Newtonian mechanics) modeled by order differential equations

**CLO6.** Construct a second solution of a differential equation from a known solution

**CLO7.** Use methods for obtaining exact solutions of linear homogeneous and nonhomogeneous differential equation.

**CLO8.** Compare the methods of solutions developed in higher order and solution in 2nd /1st order equations.

**CLO9.** Name quantitative representations of solution to problems.

#### **Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              | x    |      | x    |      |      | x    |       |       | x     |
| CLO2        | x               |           | x                              | x    |      | x    |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              | x    |      | x    |      |      | x    |       |       | x     |
| CLO4        | x               |           | x                              | x    | x    | x    |      |      | x    |       |       | x     |
| CLO5        | x               |           | x                              | x    |      | x    |      |      | x    |       |       | x     |
| CLO6        | x               |           | x                              | x    |      | x    | x    |      | x    |       |       | x     |
| CLO7        | x               |           | x                              | x    |      | x    |      | x    |      |       |       | x     |
| CLO8        | x               |           |                                | x    |      | x    |      |      | x    |       |       | x     |
| CLO9        | x               |           |                                | x    |      | x    |      |      | x    | x     |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                                                                                                        | Teaching-Learning Strategies                                                           | Assessment Strategies                                                      |
|-------------------------------|------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| CLO1                          | Classify differential equations by order, linearity, and homogeneity                                                         | Lecture, Recommended textbook, worksheets, use multimedia projector                    | Exams (Quizzes, In-course and Final written examination), assignment, viva |
| CLO2                          | Solve first/higher order linear differential equations with and without initial conditions                                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Exams (Quizzes, In-course and Final written examination), assignment, viva |
| CLO3                          | Determine regions of the plane over which a given order differential equation will have a unique solution                    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Exams (Quizzes, In-course and Final written examination), assignment, viva |
| CLO4                          | Prepare for success in disciplines which rely on differential equations.                                                     | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Exams (Quizzes, In-course and Final written examination), assignment, viva |
| CLO5                          | Analyze real-world problems modeled by order differential equations                                                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Exams (Quizzes, In-course and Final written examination), assignment, viva |
| CLO6                          | Construct a second solution of a differential equation from a known solution                                                 | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Exams (Quizzes, In-course and Final written examination), assignment, viva |
| CLO7                          | Use methods for obtaining exact solutions of linear homogeneous and nonhomogeneous differential equation.                    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Exams (Quizzes, In-course and Final written examination), assignment, viva |
| CLO8                          | Compare the methods of solutions developed in higher order and solution in 2 <sup>nd</sup> /1 <sup>st</sup> order equations. | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Exams (Quizzes, In-course and Final written examination), assignment, viva |
| CLO9                          | Name quantitative representations of solution to problems.                                                                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Exams (Quizzes, In-course and Final written examination), assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. S. L. Ross, Differential Equations, John Wiley and Sons
2. D. G. Zill, A First Course in Differential Equations with Applications, Brooks Cole
3. Earl D Rainville and Phillip E Bedient, Elementary Differential equations, Macmillan
4. F. Brauer & J. A. Nohel, Ordinary Differential Equations: A First Course, W. A. Benjamin
5. Erwin Kreyszig, Advanced engineering mathematics, John Wiley

| MTH 204: Linear Algebra II                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                         |                       |                                              |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------|----------------------------------------------|
| <b>Course Code: MTH 204</b><br><b>Course Title:</b><br><b>Linear Algebra II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>Credit Hours:</b><br><b>3.00 Hrs/Week</b><br><b>Total Marks: 100</b> | <b>Year: Second</b>   | <b>Semester:</b>                             |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Course Type:</b><br><b>Theory</b>                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br><b>2023-2026</b> |
| <p><b>Rationale:</b></p> <p>Linear algebra II is the study of vector spaces and linear mappings between them. In this course, we will begin by reviewing topics you learned in Linear Algebra I, starting with vectors, matrices and linear mappings. The review will refresh the student's knowledge of the fundamentals of vectors and of matrix theory, and how to perform operations on matrices. After the review, we can extend this idea to Similar Matrices. Next, we will focus on Linear Functional and dual Space. We will then introduce a new structure on vector spaces: an inner product. Inner products allow us to introduce geometric aspects, such as length of a vector, and to define the notion of orthogonality between vectors. In this context, we will study the applications in Linear Models and Fourier Approximation, and more. We will end this chapter with the spectral theorem, which provides a decomposition of the vector space on which operators act, and singular-value decomposition, which is a generalization of the spectral theorem to arbitrary matrices. Then, we will study Bilinear, quadratic &amp; Hermitian forms. Symmetric Matrices and Quadratic Forms, Positive Definite Matrices will be studied at the end of this course with their applications in diverse fields. The subject material is of vital importance in all fields of mathematics and in science in general.</p> |                                                                         |                       |                                              |
| <p><b>Course Objectives:</b></p> <ol style="list-style-type: none"> <li>1. Get familiar with the basic ideas and techniques of linear algebra for use in many other lecture courses</li> <li>2. Learn the fundamental concepts of linear algebra culminating in abstract vector spaces and linear transformations</li> <li>3. Understand abstract vector spaces over arbitrary fields and linear transformations, matrices, matrix algebra, similarity of matrices, inner product spaces</li> <li>4. Know some basic ideas of abstract algebra and techniques of proof which will be useful for future courses in pure mathematics</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                         |                       |                                              |
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li>1. <b>Similar Matrices:</b> Canonical forms of matrices, Symmetric, orthogonal and Hermitian matrices</li> <li>2. <b>Linear Functional and Dual Space:</b> Linear transformation and their properties. Matrix representation of linear transformations. Change of bases. Linear functional and the dual space; Dual basis, Second dual space; Annihilators; Transpose of a linear transformation</li> <li>3. <b>Orthogonality:</b> Inner product, Length and Orthogonality; Projections and Least Squares; The Gram-Schmidt process; Orthonormal sets; Inner product spaces; Linear functions and adjoints; Positive operators; unitary operators and normal operators; The spectral theorem; Application to Linear Models and Fourier Approximation</li> <li>4. <b>Bilinear, Quadratic &amp; Hermitian Forms:</b> Matrix form; transformations; canonical forms; reduction form; definite and semi-definite forms; principal minors; and factorable forms</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                            |                                                                         |                       |                                              |

|                                                                                                                                                                                                                                                                                                                                                 |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-----------|--------------------------------|----------------------------------------------------------------------------------------|------|------|------|------|------------------------------------------------------------|-------|-------|-------|
| <div>5. <b>Symmetric Matrices and Quadratic Forms:</b> Diagonalization of Symmetric Matrices; Quadratic Forms; The Singular Value Decomposition; Applications to Image Processing and Statistics</div> <div>6. <b>Positive Definite Matrices:</b> Minima, Maxima, and Saddle Points; Tests for Positive Definiteness; Minimum Principles.</div> |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>Course Learning Outcomes (CLOs):</b>                                                                                                                                                                                                                                                                                                         |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| After the successful completion of the course, students will be able to:                                                                                                                                                                                                                                                                        |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO1. know the concepts of similar and different types of matrices                                                                                                                                                                                                                                                                              |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO2. learn linear functional and dual spaces                                                                                                                                                                                                                                                                                                   |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO3. understand the concept of a linear transformation from one vector space to another and matrix representation                                                                                                                                                                                                                              |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO4. learn how to calculate an orthogonal/orthonormal basis using Gram-Schmidt process                                                                                                                                                                                                                                                         |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO5. know how to calculate Least-Squares solution and the Best Approximation                                                                                                                                                                                                                                                                   |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO6. know the concept and properties of Bilinear, Quadratic, Hermitian and Canonical form                                                                                                                                                                                                                                                      |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO7. learn how to diagonalize a matrix                                                                                                                                                                                                                                                                                                         |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO8. determine positive definite matrix, maximum and minimum points                                                                                                                                                                                                                                                                            |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO9. know the application to Image Processing and in Statistics                                                                                                                                                                                                                                                                                |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>Mapping of CLOs with PLOs:</b>                                                                                                                                                                                                                                                                                                               |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO/<br>PLO                                                                                                                                                                                                                                                                                                                                     | PLO1<br>(Funda)                  | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4                                                                                   | PLO5 | PLO6 | PLO7 | PLO8 | PLO9                                                       | PLO10 | PLO11 | PLO12 |
| CLO1                                                                                                                                                                                                                                                                                                                                            | X                                |           |                                | X                                                                                      |      | X    |      |      | X                                                          |       |       | X     |
| CLO2                                                                                                                                                                                                                                                                                                                                            | X                                |           | X                              | X                                                                                      |      | X    |      |      | X                                                          |       |       | X     |
| CLO3                                                                                                                                                                                                                                                                                                                                            | X                                |           |                                | X                                                                                      |      | X    |      |      | X                                                          |       |       | X     |
| CLO4                                                                                                                                                                                                                                                                                                                                            |                                  |           | X                              | X                                                                                      |      | X    |      |      | X                                                          |       |       | X     |
| CLO5                                                                                                                                                                                                                                                                                                                                            |                                  |           | X                              | X                                                                                      |      | X    |      |      | X                                                          |       |       | X     |
| CLO6                                                                                                                                                                                                                                                                                                                                            | X                                |           |                                | X                                                                                      |      |      |      |      |                                                            |       |       | X     |
| CLO7                                                                                                                                                                                                                                                                                                                                            |                                  |           | X                              | X                                                                                      |      | X    |      |      | X                                                          |       |       | X     |
| CLO8                                                                                                                                                                                                                                                                                                                                            | X                                |           |                                | X                                                                                      |      | X    |      |      | X                                                          |       |       | X     |
| CLO9                                                                                                                                                                                                                                                                                                                                            |                                  |           | X                              | X                                                                                      | X    | X    | X    |      | X                                                          |       |       | X     |
| <b>Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning &amp; Assessment Strategy:</b>                                                                                                                                                                                                                                            |                                  |           |                                |                                                                                        |      |      |      |      |                                                            |       |       |       |
| Course Learning Outcome (CLO)                                                                                                                                                                                                                                                                                                                   | Topic                            |           |                                | Teaching-Learning Strategies                                                           |      |      |      |      | Assessment Strategies                                      |       |       |       |
| CLO1                                                                                                                                                                                                                                                                                                                                            | Similar Matrices                 |           |                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO2                                                                                                                                                                                                                                                                                                                                            | Linear Functional and Dual Space |           |                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO3                                                                                                                                                                                                                                                                                                                                            | Orthogonality                    |           |                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO4                                                                                                                                                                                                                                                                                                                                            | Orthogonal/orthonormal basis     |           |                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |

|      |                                                   |                                                                                        |                                                            |
|------|---------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO5 | Least-Squares solution and the Best Approximation | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6 | Bilinear, Quadratic and Hermitian forms           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7 | Diagonalization of Symmetric Matrices             | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8 | Positive Definite Matrices                        | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO9 | Symmetric Matrices and Quadratic Forms            | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. H. Anton, and C. Rorres, Linear Algebra with Applications, 10th edition
2. David C. Lay, Linear Algebra and Its Applications, 4th edition
3. W. K. Nicholson, Linear Algebra with Applications, 3rd edition
4. S. Lipschutz, Linear Algebra, Schaum's Outline Series.
5. G. Strang, Linear Algebra and Its Applications, 4th edition
6. B Kolman and D R. Hill, Elementary Linear Algebra with Applications.

| MTH 205: Integral Calculus II                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                         |                       |                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 205</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>Credit Hours:</b>    | <b>Year: Second</b>   | <b>Semester:</b>         |
| <b>Course Title:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Integral Calculus II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Theory</b>           |                       | <b>2023-2026</b>         |
| <p><b>Rationale:</b></p> <p>Calculus is a branch of mathematics concerned with the calculation of instantaneous rates of change (differential calculus) and the summation of infinitely many small factors to determine some whole (integral calculus). Calculus is considered to be one of the greatest achievements of the human intellect and it is now the basic entry point for anyone wishing to study physics, chemistry, biology, economics, finance, or actuarial science. The development of calculus in the seventeenth and eighteenth centuries was motivated by the need to understand physical phenomena such as the tides, the phases of the moon, the nature of light, gravity etc.</p> |                         |                       |                          |
| <p><b>Course Objectives:</b></p> <p>As its name suggests, Integral Calculus II is the extension of Integral Calculus I, in which we study functions of a single independent variable, to more than one variable. That is, it will study functions of two or more independent variables. These functions are interesting in their own right, but they are also essential for describing the physical world. Through the use of the unifying themes of double integrals, triple integrals, line integrals and surface integrals, the course will</p>                                                                                                                                                      |                         |                       |                          |

become a cohesive whole rather than a collection of unrelated topics. By the end of the course students will know how to integrate functions of several variables and vector valued functions. In single variable calculus the Fundamental Theorem of Calculus relates derivatives to integrals. We will see something similar in this course, namely, Green's Theorem, Stokes' Theorem and Gauss' Theorem and understanding the physical significance of these theorems will be the capstone of the course.

#### **Course Contents:**

- 1. Multiple Integrals:** Double Integrals and iterated integrals; Area using double integral; Double integrals in polar form.
- 2. Triple Integrals and Iterated Integrals:** Volume using triple integrals; Triple integral in cylindrical and spherical coordinates.
- 3. Change of Variables:** General multiple integrals, Change of Variables in Multiple Integrals; Jacobians.
- 4. Integration of Vector:** Line and Surface integrals; Green's theorem; Gauss's theorem; Stokes' theorem.
- 5. Improper Integrals:** Different types of improper integrals; Test for convergence.
- 6. Integrals Depending upon a Parameter:** Differentiation and integration under the integral sign.

#### **Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

- CLO1.** Know about rectangular coordinates, cylindrical coordinates and spherical coordinates  
**CLO2.** Sketch of different types of cylindrical and quadric surfaces  
**CLO3.** Compute multiple integrals in rectangular, polar, cylindrical and spherical coordinates  
**CLO4.** Change variables in multiple integrals  
**CLO5.** Understand of physical significance of gradient, divergence and curl  
**CLO6.** Understand flux, surface integrals for flux, and volume integrals  
**CLO7.** Understand Green's, Stokes', Gauss' theorems  
**CLO8.** Test the convergence of improper integrals  
**CLO9.** Understand differentiation and integration under the integral sign

#### **Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              | x    |      | x    |      |      |      |       |       |       |
| CLO2        | x               |           |                                | x    |      | x    |      |      |      |       |       |       |
| CLO3        | x               |           | x                              | x    |      |      | x    |      |      |       |       | x     |
| CLO4        | x               | x         | x                              | x    |      | x    | x    |      |      |       |       |       |
| CLO5        | x               |           | x                              | x    |      | x    | x    |      |      |       |       |       |
| CLO6        | x               |           |                                | x    |      | x    |      |      |      |       |       |       |
| CLO7        | x               |           | x                              | x    |      | x    |      |      |      |       |       |       |
| CLO8        | x               |           | x                              |      |      | x    |      |      |      |       |       |       |
| CLO9        | x               |           | x                              | x    |      | x    |      |      |      |       |       |       |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                                                                   | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|-----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | Coordinate transformations                                                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | Sketch of different types of cylindrical and quadric surfaces                           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | Compute multiple integrals in rectangular, polar, cylindrical and spherical coordinates | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                          | About change variables in multiple integrals                                            | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                          | Physical significance of gradient, divergence and curl                                  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                          | Know about flux, surface integrals for flux, and volume integrals                       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                          | Green's, Stokes', Gauss' theorems                                                       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8                          | Test the convergence of improper integrals                                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO9                          | Differentiation and integration under the integral sign                                 | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. H. Anton, I. C. Bivens and S. Davis, Calculus: Early Transcendentals, Wiley.
2. E. W. Swokowski, Calculus with Analytic Geometry, Brooks/Cole.
3. G. B. Thomas and R. L. Finney, Calculus and Analytic Geometry, Addison Wesley.
4. J. Stewart, Multi Variable Calculus: Early Transcendentals, Cengage Learning.
5. W. Rudin, Principle of Mathematical Analysis.

| MTH 206: Numerical Analysis I             |                                    |                       |                                    |
|-------------------------------------------|------------------------------------|-----------------------|------------------------------------|
| <b>Course Code: MTH 206</b>               | <b>Credit Hours: 3.00 Hrs/Week</b> | <b>Year: Second</b>   | <b>Semester:</b>                   |
| <b>Course Title: Numerical Analysis I</b> | <b>Total Marks: 100</b>            |                       |                                    |
| <b>Course Teacher:</b>                    | <b>Course Type: Theory</b>         | <b>Pre-requisite:</b> | <b>Academic Session: 2023-2026</b> |

**Rationale:**

Numerical Method is an important branch in Mathematics as well as Engineering. It aims at numerically solving all kinds of mathematical problems which arise from practical applications and can be modeled by different mathematical equations.

**Course Objectives:**

1. To gain the knowledge on several traditional but popular and effective numerical methods for solving nonlinear equations of one variable.
2. Students will know the basic properties and operations for matrices and vectors, and then presents some most fundamental numerical algorithms for linear systems.
3. Students will learn a simple and often efficient methodology to extract a good approximation to some given function or data by interpolation.
4. The course comes closer to our aforementioned aim, when we discuss numerical integration and differentiation.

**Course Contents:**

1. **Approximation and Errors in Computing:** Introduction, Significant digits, Inherent error, Rounding error, Truncation error, Absolute and relative error, Error propagation, Rates of Convergence.
2. **Solutions of Equations in One Variable:** Bisection method, Method of false position. Fixed point iteration, Newton-Raphson method, Error Analysis for iterative method. Accelerating rate of convergence.
3. **Interpolation and Polynomial Approximation:** Interpolation and Extrapolation, Lagrange interpolating polynomials, Newton's divided-difference formula, Newton's forward and backward difference formulas, Cubic spline approximations. Iterated interpolation, Richardson's extrapolation.
4. **Numerical Differentiation and Integration:** Numerical differentiation, Elements of Numerical Integration (Composite Trapezoid/Simpson's/Weddle's/Midpoint rules), Adaptive quadrature method, Romberg's integration, Gaussian quadrature.
5. **Solutions of Linear Systems:** Gaussian elimination and backward substitution, with pivoting strategies, LU decomposition method, Jacobi method, Gauss-Seidel method, SOR method.
6. **Initial Value Problems for ODE:** Euler's and modified Euler's method, Runge-Kutta methods.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

- CLO1.** Students will learn the definition of Floating point.
- CLO2.** To gather knowledge about different types of Error.
- CLO3.** Students will learn about Algorithm and Convergence.
- CLO4.** Learn how to find roots of an equation by using different root findings method.
- CLO5.** Apply various techniques to solve the system of linear equations using various numerical methods.
- CLO6.** Explain and understand how to use Newton's divided difference technique.
- CLO7.** Could apply Spine quadrature and adaptive quadrature in some real life problems.

**CLO8.** The readers will capture the knowledge of how to integrate numerically by using integral methods.

**CLO9.** Students will learn the concept of first order differential equations and will be able to solve the differential equations using different numerical methods of ODE.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           |                                |      |      |      |      |      |      |       |       | x     |
| CLO8        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |
| CLO9        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                             | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|---------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | <b>Solution of equation in one variable</b>       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | <b>Interpolation and polynomial approximation</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | <b>Differentiation and Integration</b>            | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                          | <b>Solutions of linear systems</b>                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. R.L. Burden & J. D. Faires, Numerical Analysis.
2. M. A. Celia & W. G. Gray, Numerical Methods for Differential Equations.
3. L.W. Johson & R. D. Riess, Numerical Analysis.
4. Stephen C. Chapra, Applied Numerical Methods with MATLAB for Engineers and Scientists

| MTH 207: Discrete Mathematics |                         |                     |                  |
|-------------------------------|-------------------------|---------------------|------------------|
| <b>Course Code: MTH 207</b>   | <b>Credit Hours:</b>    | <b>Year: Second</b> | <b>Semester:</b> |
| <b>Course Title:</b>          | <b>3.00 Hrs/Week</b>    |                     |                  |
| <b>Discrete Mathematics</b>   | <b>Total Marks: 100</b> |                     |                  |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                      |                       |                                              |      |      |      |      |      |      |       |       |       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-----------------------|----------------------------------------------|------|------|------|------|------|------|-------|-------|-------|
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Course Type:</b><br><b>Theory</b> | <b>Pre-requisite:</b> | <b>Academic Session:</b><br><b>2023-2026</b> |      |      |      |      |      |      |       |       |       |
| <b>Rationale:</b><br><br>Discrete mathematics deals with fundamental ideas of reasoning, counting, recurrence relations and graph theory. Understanding of this course will help students to learn the bridging of mathematics with computer science. After completion of this course, students will get some useful and applicable ideas on mathematical logic, recurrence relations, generating functions, different graphs. It will enable them to use algorithms on graphs to solve some well-known problems.                                                                                                                                                                                                                                                                                                                                                                                              |                                      |                       |                                              |      |      |      |      |      |      |       |       |       |
| <b>Course Objectives:</b><br><br><div><div></div><div>1. To give knowledge on some basic mathematical concepts in discrete mathematics and their applications.</div><div>2. To provide brief knowledge of use of logical inferences, different methods of proofs.</div><div>3. To introduce elementary graph theory and some algorithms of computational mathematics.</div><div>4. Students will learn about the bridging of discrete mathematics with computer science.</div></div>                                                                                                                                                                                                                                                                                                                                                                                                                           |                                      |                       |                                              |      |      |      |      |      |      |       |       |       |
| <b>Course Contents:</b><br><br><div><div></div><div>1. <b>Mathematical Reasoning:</b> Inference and fallacies; methods of proof; complexity of algorithms; recursive definitions.</div><div>2. <b>Counting:</b> Counting principles; inclusion-exclusion principle; pigeonhole principle; generating functions; recurrence relations; applications to computer operations.</div><div>3. <b>Graphs and Trees:</b> Introduction to graphs, paths and trees; structure and symmetry of graphs; paths and connectivity; Eulerian and Hamiltonian paths; directed graphs; shortest path problems: Dijkstra's algorithm, Floyd-Warshall algorithm and their comparisons; planar graphs; tree traversal; Spanning tree problems: Kruskal's greedy algorithm, Prim's greedy algorithm and their comparison.</div><div>4. <b>Boolean Algebra:</b> Boolean functions; logic gates; minimization of circuits.</div></div> |                                      |                       |                                              |      |      |      |      |      |      |       |       |       |
| <b>Course Learning Outcomes (CLOs):</b><br><br>After the successful completion of the course, students will be able to:<br><br><b>CLO1.</b> Analyze logical propositions via truth tables.<br><b>CLO2.</b> Prove mathematical theorems using mathematical induction.<br><b>CLO3.</b> Understand sets and perform operations and algebra on sets.<br><b>CLO4.</b> Determine properties of relations, identify equivalence and partial order relations, sketch relations.<br><b>CLO5.</b> Identify functions and determine their properties.<br><b>CLO6.</b> Define graphs, digraphs and trees, and identify their main properties.<br><b>CLO7.</b> Evaluate combinations and permutations on sets.                                                                                                                                                                                                              |                                      |                       |                                              |      |      |      |      |      |      |       |       |       |
| <b>Mapping of CLOs with PLOs:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                      |                       |                                              |      |      |      |      |      |      |       |       |       |
| CLO/<br>PLO                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | PLO1<br>(Funda)                      | PLO2(Lab)             | PLO3<br>(Critical<br>Thinking)               | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
| CLO1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | x                                    |                       | x                                            |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | x                                    |                       | x                                            |      |      |      |      | x    | x    |       |       | x     |

|      |   |   |   |   |   |   |  |  |  |   |   |   |
|------|---|---|---|---|---|---|--|--|--|---|---|---|
| CLO3 | x |   |   |   |   |   |  |  |  |   | x | x |
| CLO4 | x | x | x | x |   |   |  |  |  | x |   | x |
| CLO5 | x |   | x | x | x | x |  |  |  |   |   | x |
| CLO6 | x |   | x |   |   |   |  |  |  |   |   | x |
| CLO7 | x |   | x |   |   | x |  |  |  |   |   | x |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                           | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|-------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1<br>CLO2                  | Mathematical reasoning and counting             | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | Recurrence relations                            | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4<br>CLO5                  | Properties of graph                             | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                          | Identify the differences among graphs and trees | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                          | Boolean Algebra                                 | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. K. H. Rosen, An Introduction to Discrete Mathematics and Its Applications, McGraw-Hill Education.
2. C. L Liu, Elements of Discrete Mathematics, McGraw-Hill Education
3. R. Kolman, R. C. Bushy, S. Ross, Discrete Mathematical Structures, Prentice Hall
4. R. P. Grimaldi and B. V. Ramana, Discrete and Combinatorial Mathematics: An Applied Introduction, Pearson Education, Inc.
5. S. Lipschutz and M. Lipson, Discrete Mathematics, Schaum's Outline Series.

| MTH 208: Programming Fundamentals                                                      |                                                                         |                       |                                              |
|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------|----------------------------------------------|
| <b>Course Code: MTH 208</b><br><b>Course Title:</b><br><b>Programming Fundamentals</b> | <b>Credit Hours:</b><br><b>3.00 Hrs/Week</b><br><b>Total Marks: 100</b> | <b>Year: Second</b>   | <b>Semester:</b>                             |
| <b>Course Teacher:</b>                                                                 | <b>Course Type:</b><br><b>Theory</b>                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br><b>2023-2026</b> |

**Rationale:**

Programming Fundamentals is the basic foundation course for mathematical programming. Students will learn the basics of program design techniques. After completion of this course they will be able to solve mathematical and scientific problems through computer program. Though

programming language covered here is Fortran but students will be able to learn other languages for mathematical programming very quickly after completion of this course.

**Course Objectives:**

1. To give basic knowledge on Computer system and data representation.
2. To give knowledge on basic program design techniques.
3. To give idea about structure of a computer program and basic elements of programming language FORTRAN.
4. To give knowledge about use of various control structures and arrays in FORTRAN.
5. To give knowledge about formatted I/O and how to use file for I/O data.
6. To give knowledge about use of subroutine and user defined function in FORTRAN.
7. To give knowledge on how to construct FORTRAN program in order to solve mathematical and scientific problems.

**Course Contents:**

1. **Brief Introduction to Computer:** Computer system, Information Processing Cycle, Operating System, Data representation in Computer.
2. **Programming Language:** FORTRAN and its History, Evolution of FORTRAN.
3. **Basic Elements of FORTRAN:** Character set, Structure of Fortran statement, Program Structure, Data type, Constants, Variables, Operators and Operations, Intrinsic Functions, List directed I/O.
4. **Program Design:** Top down design technique, Pseudocode, Algorithms, Flowcharts, and Control Structures: Branches, Loops.
5. **Arrays:** One and two dimensional array.
6. **Input/output Concept:** Formatted I/O, Introduction to File Processing.
7. **Subprogram:** Function Subprogram and Subroutine, User defined function.
8. **Implementation:** Construction of FORTRAN program for problems drawn from mathematics and sciences including root finding problem for equation of one variable, IVP.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

- CLO1.** Earn basic knowledge on Computer, computer operating system and so on.
- CLO2.** Learn about basic elements of FORTRAN language.
- CLO3.** Construct a program structure and basic of program design in FORTRAN.
- CLO4.** Use of various control structures in FORTRAN.
- CLO5.** Know about various loops and their usefulness.
- CLO6.** Acquire knowledge about formatted I/O and how to use file for I/O data, arrays.
- CLO7.** Use of subroutine and user defined function in FORTRAN.
- CLO8.** Construct FORTRAN program in order to solve mathematical and scientific problems.
- CLO9.** Finally, students will solve number of problems using FORTRAN language and develop their knowledge of Algorithm.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
|             |                 |           |                                |      |      |      |      |      |      |       |       |       |

|      |   |   |   |   |  |   |  |  |  |  |  |   |
|------|---|---|---|---|--|---|--|--|--|--|--|---|
| CLO1 | × |   |   |   |  |   |  |  |  |  |  | × |
| CLO2 | × |   |   |   |  |   |  |  |  |  |  | × |
| CLO3 | × | × | × | × |  |   |  |  |  |  |  | × |
| CLO4 |   | × | × | × |  |   |  |  |  |  |  | × |
| CLO5 |   | × |   | × |  |   |  |  |  |  |  | × |
| CLO6 |   | × |   | × |  |   |  |  |  |  |  | × |
| CLO7 |   | × |   | × |  |   |  |  |  |  |  | × |
| CLO8 |   | × | × | × |  | × |  |  |  |  |  | × |
| CLO9 |   | × | × | × |  | × |  |  |  |  |  | × |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                          | Teaching-Learning Strategies                                            | Assessment Strategies                                    |
|-------------------------------|--------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------|
| CLO1                          | Brief Introduction to Computer | Lecture, recommended textbooks, worksheets.                             | In-course exam and final written exam, assignment, viva. |
| CLO2                          | Programming Language           | Lecture, recommended textbooks, worksheets.                             | In-course exam and final written exam, assignment, viva. |
| CLO3                          | Basic Elements of FORTRAN      | Lecture, recommended textbooks, worksheets, using multimedia projector. | In-course exam and final written exam, assignment, viva. |
| CLO4<br>CLO5                  | Program Design                 | Lecture, recommended textbooks, worksheets, using multimedia projector. | In-course exam and final written exam, assignment, viva. |
| CLO6                          | Arrays, Input/output concept   | Lecture, recommended textbooks, worksheets, using multimedia projector. | In-course exam and final written exam, assignment, viva. |
| CLO7                          | Subprogram                     | Lecture, recommended textbooks, worksheets, using multimedia projector. | In-course exam and final written exam, assignment, viva. |
| CLO8<br>CLO9                  | Implementation                 | Lecture, recommended textbooks, worksheets, using multimedia projector. | In-course exam and final written exam, assignment, viva. |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. Introduction to FORTRAN 90/95 for Scientists and Engineers by Stephen J. Chapman.
2. Modern FORTRAN Explained by Michael Metcalf, John Reid and Malcolm Cohen.
3. Introduction to Programming with FORTRAN by Ian Chivers and Jane Sleightholme.
4. Numerical Methods of Mathematics Implemented in FORTRAN by S.K. Bose.

| MTH 250: Math Lab II (MATLAB)         |                                   |                |                                |
|---------------------------------------|-----------------------------------|----------------|--------------------------------|
| Course Code: MTH 250                  | Credit Hours:                     | Year: Second   | Semester:                      |
| Course Title:<br>Math Lab II (MATLAB) | 3.00 Hrs/Week<br>Total Marks: 100 |                |                                |
| Course Teacher:                       | Course Type:<br>Lab               | Pre-requisite: | Academic Session:<br>2023-2026 |

**Rationale:**

MATLAB (stands for Matrix Laboratory) is the advanced fourth-generation programming language that is widely employed to create an easy-to-perform environment for the mathematical notations. Its best applications include Data Analysis, Mathematics and Computation, Algorithm Developments, Visualization, etc. The MATLAB teach you how to use this tool for symbolic computation and developing algorithms. Graduates, Post Graduates, Working Professionals, Researchers and Developers can enroll in these courses to develop expertise in the basic functionalities of MATLAB software.

**Course Objectives:**

1. Use programming operations to calculate solutions
2. Determine better and more accurate solutions
3. Perform and evaluate algebraic and trigonometric operations using built-in functions
4. Assign and manage variables
5. Manipulate vectors and matrices, use matrix indexing, and determine matrix dimensions
6. Generate linearly spaced vectors
7. Create and execute a script
8. Create and evaluate x-y plots and subplots suitable for technical presentation
9. Create, test, and execute user-defined functions and sub-functions
10. Create function input validation
11. Distinguish between the different MATLAB 'data types'
12. Create and manipulate Structures and Arrays
13. Perform and evaluate relational and logical operations
14. Load, analyze, and manipulate images
15. Obtain and utilize user input
16. Manage and format text output
17. Import and export numeric data using other filetypes (e.g. .csv, .xls, and .txt)
18. Perform polynomial curve-fitting, general curve fitting, and interpolation
19. Perform numeric and symbolic differentiation and integration
20. Solve non-linear systems of equations
21. Solve numeric ODE's
22. Build a block diagram in Simulink to perform an operation
23. Perform numerical optimization
24. Analyze Signals

**Course Contents:**

1. Problems Solving: Problems in the courses of Second Year BS Honours will be solved using Computer Algebra System (CAS) MATLAB.
2. Lab Assessment: Take Class Test.
3. Lab Assignments: Course instructors will provide a list of Lab assignments.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

- CLO1.** Understanding MATHEMATICA/ MATLAB/ FORTRAN/ C/ Maple.  
**CLO2.** Apply any of the programming language in higher study.

**CLO3.** Solve real life problem using the programming language.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                   | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|-------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                                   | <b>Problems Solving</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                                   | <b>Lab Assessment</b>   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                                   | <b>Lab Assignments</b>  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** Internal Assessment: **40 Marks**, Final Examination (Lab 3 Hours): **60 Marks**.

**Four (04)** questions of equal value will be set, of which **All Questions** are to be answered.

**References:**

1. MATLAB for Engineers, 6th edition, Holly Moore, Salt Lake Community College, Pearson Education Inc, 2022
2. Introduction to Scientific Computing by Charles F. Van Loan
3. Numerical Computing with Matlab" by Cleve Moler
4. MATLAB Handbook with Applications to Mathematics, Science, Engineering, and Finance by Jose Miguel David Baez-Lopez, David Alfredo Baez Villegas, Copyright 2019
5. Mathematical Modeling and Simulation with MATLAB, Sheldon Lee, La Crosse, WI Megan Buzby, Juneau, AK, Copyright Year: 2021
6. Advanced Engineering Mathematics with MATLAB, 5th edition, Dean G. Duffy, USNA, CRC Press, Inc., 2021

**MTH 299: Viva Voce**

**Credits: 2**

**Viva Voce on courses taught in the Second Year.**

**Curriculum for Four-Year BS Honours Program**  
**Department of Mathematics**  
**University of Dhaka**



**List of Departmental Courses for Third Year**  
**(35 Credits)**  
**(Effective for 2023-2024 and onwards)**

| Course No.     | Course Name                           | Credits   |
|----------------|---------------------------------------|-----------|
| <b>MTH 301</b> | Real Analysis II                      | 3 credits |
| <b>MTH 302</b> | Complex Analysis                      | 3 credits |
| <b>MTH 303</b> | Ordinary Differential Equations II    | 3 credits |
| <b>MTH 304</b> | Abstract Algebra                      | 3 credits |
| <b>MTH 305</b> | Fundamentals of Topology              | 3 credits |
| <b>MTH 306</b> | Numerical Analysis II                 | 3 credits |
| <b>MTH 307</b> | Mathematical Methods                  | 3 credits |
| <b>MTH 308</b> | Optimization                          | 3 credits |
| <b>MTH 309</b> | Stochastic calculus                   | 3 credits |
| <b>MTH 310</b> | Introduction to Actuarial Mathematics | 3 credits |
| <b>MTH 350</b> | Math Lab III (FORTRAN)                | 3 credits |
| <b>MTH 399</b> | Viva Voce                             | 2 credits |

| MTH 301: Real Analysis II                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                         |                       |                                              |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------|----------------------------------------------|
| <b>Course Code: MTH 301</b><br><b>Course Title:</b><br><b>Real Analysis II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Credit Hours:</b><br><b>3.00 Hrs/Week</b><br><b>Total Marks: 100</b> | <b>Year: Third</b>    | <b>Semester:</b>                             |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Course Type:</b><br><b>Theory</b>                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br><b>2023-2026</b> |
| <p><b>Rationale:</b></p> <p>This course is a continuation of the elementary analysis of functions of single real variables to the elementary analysis of functions of several variables. To facilitate the analysis, the required topological ideas of metric spaces. Their elementary properties and the basics of functions defined on a metric space are the objects of study at the beginning of the course. The course provides the main background needed in modern Advanced Mathematical Analysis.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                         |                       |                                              |
| <p><b>Course Objectives:</b></p> <p>Along with the study of the properties of functions defined on a metric space the prime objectives of the course are the study of the properties of Differentiation and Integration of functions of several real variables. For example, limit, Continuity, Differentiability, Chain rule of differentiation, Jacobian, implicit and inverse function theorems, Riemann integrals of functions of several variables, Fubini's theorem and Change of variables, etc.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                         |                       |                                              |
| <p><b>Course Contents:</b></p> <p>It is intended to cover the following topics, not necessarily exactly in the given order. Any variation from this will be indicated by the Instructor.</p> <ol style="list-style-type: none"> <li><b>1. Sequence of Functions:</b> Pointwise and Uniform convergence. Interchangeability of limiting processes. Power series. Differentiation and integration of power series. Abel's continuity theorem.</li> <li><b>2. Metric Space:</b> Definition and examples. Open and closed sets, Equivalent metrics, Cauchy sequence and completeness, compactness.</li> <li><b>3. Differentiation:</b> Definition and properties of derivative a function of several variables, implicit, and inverse function theorems with some applications.</li> <li><b>4. Integration:</b> Definition and properties of the integral of functions of several variables, Fubini's theorem, and Change of variables.</li> </ol> |                                                                         |                       |                                              |
| <p><b>Course Learning Outcomes (CLOs):</b></p> <p>After the successful completion of the course, students will be able to:</p> <p><b>CLO1.</b> Elementary topological properties of a metric space.</p> <p><b>CLO2.</b> Success of infinite sequence and series of functions defined of a metric space.</p> <p><b>CLO3.</b> Elementary analysis of functions of several variables. Limit, continuity, differentiability of a function, for example.</p> <p><b>CLO4.</b> Applications of partial derivatives in optimization of a function.</p> <p><b>CLO5.</b> Applications of inverse and implicit function theorem.</p> <p><b>CLO6.</b> Evaluation of multiple integrals using Fubini's theorem.</p>                                                                                                                                                                                                                                         |                                                                         |                       |                                              |

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              | x    | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              | x    |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              | x    |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              | x    |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              | x    |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              | x    |      |      |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                                           | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                                   | Sequence of Functions                                           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                                   | Metric Space                                                    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                                   | Infinite sequences in metric spaces and their convergence       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                                   | Continuity and uniform continuity of functions on metric spaces | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                                   | Compactness in metric spaces                                    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                                   | Differentiation and integration in $\mathbb{R}^n$               | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. C. G. C. Pitts, Introduction to Metric Spaces.
2. R. G. Bartle, Elements of Real Analysis.
3. W. Rudin, Principles of Mathematical Analysis.
4. T. M. Apostol, Advanced Calculus.
5. C. H. Edward, Jr., Advanced Calculus of several variables.

**MTH 302: Complex Analysis**

|                             |                         |                    |                  |
|-----------------------------|-------------------------|--------------------|------------------|
| <b>Course Code: MTH 302</b> | <b>Credit Hours:</b>    | <b>Year: Third</b> | <b>Semester:</b> |
| <b>Course Title:</b>        | <b>3.00 Hrs/Week</b>    |                    |                  |
| <b>Complex Analysis</b>     | <b>Total Marks: 100</b> |                    |                  |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                       |                                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------|---------------------------------------|
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Course Type:</b><br>Theory | <b>Pre-requisite:</b> | <b>Academic Session:</b><br>2023-2026 |
| <p><b>Rationale:</b></p> <p>Complex analysis, which is mainly the theory of complex functions of a complex variable. The course is introduced to the basic idea of the complex plane, along with the algebra and geometry of complex numbers, and then move on to differentiation, integration, complex dynamics, power series representation and Laurent series. Majorly this course contains the integration of a complex function and theorems related to complex integration. Also the course contains the general representation of complex numbers and functions with the special idea of different complex mappings too. After completing the course, students will gain the basic ideas of complex numbers, complex functions and theorems related to complex differentiation, integration and applications of these theorems to solve different mathematical problems.</p>                                                                                                                                                                                                                                                                                                               |                               |                       |                                       |
| <p><b>Course Objectives:</b></p> <ol style="list-style-type: none"> <li>1. To develop the basic ideas complex numbers and functions.</li> <li>2. To learn the ideas of limit, continuity and differentiability of complex functions, theorems related to differentiation of complex function.</li> <li>3. Understanding the Harmonic function, Analytic function and Cauchy-Riemann equation.</li> <li>4. Learning the basic properties of integration of complex functions, theorems on complex integration and use of these theorems to solving mathematical problems.</li> <li>5. Understanding the ideas of Taylor and Laurent series and the singularities.</li> <li>6. Understanding the basics of Conformal mapping and Bilinear transformation.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                |                               |                       |                                       |
| <p><b>Course Contents:</b></p> <p>It is intended to cover the following topics, not necessarily exactly in the given order. Any variation from this will be indicated by the Instructor.</p> <ol style="list-style-type: none"> <li>1. <b>Complex Plane:</b> Metric properties and geometry of the complex plane. The point at infinity. Stereographic projection.</li> <li>2. <b>Functions of a Complex Variable:</b> Limit, continuity and differentiability of a complex function. Analytic functions and their properties. Harmonic functions.</li> <li>3. <b>Complex Integration:</b> Line integration over rectifiable curves. Winding number. Cauchy's theorem. Cauchy's integral formula. Liouville's theorem. Fundamental theorem of Algebra. Rouché's theorem. The maximum and the minimum modulus principle.</li> <li>4. <b>Singularities:</b> Power series of complex terms. Residues, Taylor's and Laurent's expansion. Cauchy's residue theorem. Evaluation of integrals by contour integration. Branch points and cuts.</li> <li>5. <b>Bilinear Transformations and Mappings:</b> Basic mapping. Linear fractional transformations. Other mappings. Conformal mappings.</li> </ol> |                               |                       |                                       |
| <p><b>Course Learning Outcomes (CLOs):</b></p> <p>After the successful completion of the course, students will be able to:</p> <p><b>CLO1.</b> Understand complex numbers and complex functions.</p> <p><b>CLO2.</b> Understand the basic concepts of limit, continuity and differentiability of complex function.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                               |                       |                                       |

**CLO3.** Understand the analytic function and Cauchy-Riemann equation.  
**CLO4.** Understand the integration of complex functions and theorems related to complex integration  
**CLO5.** Solve some difficult integration using the theorems involving complex function  
**CLO6.** Understand the infinite series and singularities  
**CLO7.** Understand the ideas of Conformal mapping and Bilinear transformation.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           |                                |      |      |      |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                        | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|----------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                                   | <b>Complex Plane</b>                         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2<br>CLO3                           | <b>Functions of a Complex Variable</b>       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4<br>CLO5                           | <b>Complex Integration</b>                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                                   | <b>Singularities</b>                         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                                   | <b>Bilinear transformations and mappings</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. R.V. Churchill & J.W. Brown, Complex Variables and Applications.
2. L. Penniri, Elements of Complex Variables.
3. L.V. Ahlfors, Complex Analysis, McGraw-Hill
4. D G Zill, Complex Variables.
5. Murray R. Spiegel, Complex Variables, Schaums Outline Series.

| MTH 303: Ordinary Differential Equations II                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                         |                       |                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 303</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Credit Hours:</b>    | <b>Year: Third</b>    | <b>Semester:</b>         |
| <b>Course Title:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Ordinary Differential Equations II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Theory</b>           |                       | <b>2023-2026</b>         |
| <p><b>Rationale:</b></p> <p>This course will focus on advance topics in ordinary differential equations. It will analyze existence and uniqueness theorem of ODE. It will also study on series solutions of second ordered linear ordinary equations. This course will also focus on Legendre functions, Bessel's function and Hermite polynomials.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |                       |                          |
| <p><b>Course Objectives:</b></p> <ol style="list-style-type: none"> <li>1. To provide methods for solving differential equations arising in physical sciences models together with their formulation</li> <li>2. To help students use transform methods to solve ordinary differential equations</li> <li>3. To enable students, explain the mathematical formulation of ODEs and their application.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                         |                       |                          |
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li>1. <b>Existence and Uniqueness Theory:</b> Fundamental existence and uniqueness theorem. Dependence of solutions on initial conditions and equation parameters. Existence and uniqueness theorems for systems of equations and higher-order equations. Methods of successive approximations, Picard's method, Peano's existence theorem, continuation of solutions (1D cases).</li> <li>2. <b>Stability Analysis of 2D System:</b> Phase Plane. Critical Points. Stability of linear and nonlinear systems differential equations. Limit Cycles and Periodic Solutions.</li> <li>3. <b>Series Solutions of Second Order Linear Equations:</b> Taylor series solutions about an ordinary point. Frobenius series solutions about regular singular points.</li> <li>4. <b>Bessel Functions:</b> Generating function, recurrence relations, Bessel differential equation, Integral representations Orthogonality relations, Modified Bessel functions.</li> <li>5. <b>Legendre Functions:</b> Generating function, recurrence relations and other properties of Legendre polynomials, Expansion theorem, Legendre differential equation, Legendre function of first kind, Legendre function of second kind, associated Legendre functions.</li> <li>6. <b>Chebyshev Function:</b> Chebyshev differential equation, Chebyshev Polynomials, Generating function, recurrence relations, Approximation of Functions by Chebyshev Polynomials</li> <li>7. <b>Special Functions:</b> Hermite &amp; Laguerre polynomials, Gamma function. Error function. Hyper geometric equation, special hyper geometric function, Generalized hyper geometric function, special confluent hyperbolic functions.</li> </ol> |                         |                       |                          |
| <p><b>Course Learning Outcomes (CLOs):</b></p> <p>After the successful completion of the course, students will be able to:</p> <p><b>CLO1.</b> provide methods for solving differential equations arising in physical sciences models together with their formulation</p> <p><b>CLO2.</b> help students use transform methods to solve ordinary differential equations.</p> <p><b>CLO3.</b> enable students explain the mathematical formulation of ODEs and their application.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                         |                       |                          |

- CLO4.** master the theory for systems of first order linear differential equations (determine fix points and periodic orbits and their stability properties)
- CLO5.** be able to formulate, prove and apply existence and uniqueness theorems (Picard's method and Peano's theorem)
- CLO6.** know the elementary theory of differential inequalities and its applications
- CLO7.** be able to use power series techniques for solutions of differential equations.
- CLO8.** be able to formulate, prove and apply the theorem about the dependence of the solutions on initial data and parameters
- CLO9.** master elementary techniques for boundary value problems

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           |                                |      |      |      |      |      |      |       |       | x     |
| CLO8        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |
| CLO9        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                                | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | Existence and uniqueness theory                      | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | Series solutions of second order linear equations    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | Legendre functions                                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                          | Bessel functions                                     | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                          | Hermite & Laguerre polynomials                       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6<br>CLO7                  | Special functions                                    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8<br>CLO9                  | Systems of linear first order differential equations | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks.** Final Examination (Theory, 3 Hours): **70 Marks.**

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. S. L. Ross, Differential Equations
2. D. G. Zill, A First Course in Differential Equations with Applications.
3. F. Brauer & J. A. Nohel, Differential Equations.
4. H. J. H. Piaggio, An Elementary Treatise on Differential Equations.
5. W.N. Lebedev & R. A. Silverman, Special Functions and their Applications.

**MTH 304: Abstract Algebra**

|                                          |                                                 |                       |                                       |
|------------------------------------------|-------------------------------------------------|-----------------------|---------------------------------------|
| <b>Course Code: MTH 304</b>              | <b>Credit Hours:</b>                            | <b>Year: Third</b>    | <b>Semester:</b>                      |
| <b>Course Title:</b><br>Abstract Algebra | <b>3.00 Hrs/Week</b><br><b>Total Marks: 100</b> |                       |                                       |
| <b>Course Teacher:</b>                   | <b>Course Type:</b><br>Theory                   | <b>Pre-requisite:</b> | <b>Academic Session:</b><br>2023-2026 |

**Rationale:**

Abstract algebra is the set of advanced topics of Algebra that deal with abstract algebraic structures rather than the usual number systems. It aims to find general underlying principles common to the usual operations (addition, multiplication, etc.) on diverse sets such as set of integers, polynomials, matrices, permutations, and much more. Students will learn in particular about the most important abstract algebraic structures which are groups, rings, and fields. It gives to student a good mathematical maturity and enables to build mathematical thinking and skill. Important branches of abstract algebra are commutative algebra, representation theory, homological algebra, Algebraic Geometry etc.

**Course Objectives:**

1. Introduce students to the basic concepts of algebraic structures embedded in Group and Ring Theories.
2. Explain to students the role commutativity plays in Abstract Algebra.
3. Demonstrate to students that there is a partial converse of Lagrange theorem.
4. Capture the canonical homomorphism via normality leading to isomorphism of two groups.
5. Demonstrate to students that this is a branch of pure mathematics of which applications to real life situations is still employable.
6. Emphasize the fact that abstract concepts arise from the analysis of concrete situations.
7. Develop student's power to think for himself in terms of concepts, include a variety of examples on each topic.
8. Capture the canonical homomorphism via normality leading to isomorphism of two groups.
9. Upon completion of this course, students may take Advanced Abstract Algebra or other advanced fields with Applications.

**Course Contents:**

### Group A: Groups

1. **Group:** Groupoids. Semigroups. Monoids. Order of an element of a group. Cyclic group. Dihedral Groups, Matrix Groups.
2. **Subgroup and Coset:** Subgroups. Algebra of complexes. Subgroup generated by a complex. Cosets. Coset decompositions. Lagrange's theorem. Normal subgroups. Quotient (factor) groups. Product of cosets.
3. **Permutation Group:** Permutation groups. Symmetric groups of permutations. Cyclic permutations. Transpositions. Even and odd permutations. Altering groups.
4. **Group Morphisms:** Homomorphisms and isomorphisms of groups. Cayley's theorem. Automorphism. Inner automorphism. Outer automorphism. The isomorphism theorems.

### Group B: Rings

5. **Ring:** Rings. Various types of rings. Properties of rings. Characteristic of a ring.
6. **Subring and Ideal:** Subring. Ideal. Principle ideal. Maximal ideal. Prime ideal. Quotient ring.
7. **Ring Morphisms:** Homomorphism of rings. Isomorphism theorems. Embedding of an integral domain in a field
8. **Domains:** Divisibility. Units. Associates. Highest common factor (HCF). Least common multiple (LCM). Coprimes. Prime elements. Irreducible elements. Principal ideal domains. Euclidean domains. Unique factorization domains.

### Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

**CLO1.** Define equivalence relation and equivalence class and determine, with complete justification, whether or not a given relation is an equivalence relation and, if so, identify equivalence classes.

**CLO2.** State the Well-Ordering Principle of the positive integers and use it in a proof.

**CLO3.** Define left-inverse, right-inverse and inverse of a function; and identify examples and non-examples of each, and prove the equivalence of one-to-one and existence of a left-inverse, and the equivalence of onto with existence of a right inverse.

**CLO4.** Demonstrate familiarity with the definition of a group and be able to test a set with binary operation to determine if it is a group.

**CLO5.** Construct a Cayley table for a group.

**CLO6.** Demonstrate familiarity with the common groups.

**CLO7.** Compute the order of a group, the order of a subgroup, and the order of an element.

**CLO8.** Identify subgroups of a given group.

**CLO9.** Identify cyclic groups and apply the fundamental theorem of cyclic groups.

**CLO10.** Demonstrate familiarity with permutation groups and be able to decompose permutations into 2- cycles.

**CLO11.** Define the concepts of homomorphism, isomorphism, and automorphism and check whether a given function defines one of these.

**CLO12.** Prove the common properties of homomorphism.

**CLO13.** Define the external direct product and be able to compute the direct product of groups.

**CLO14.** Apply Lagrange's theorem.

**CLO15.** Define normal subgroups and be able to prove that given subgroups are normal.

- CLO16.** State and apply the fundamental theorem of finite Abelian groups.
- CLO17.** Give a definition of ring and cite a variety of common examples and non-examples (finite and infinite, polynomials, and matrices).
- CLO18.** Give the definition of field and cite a variety of common examples and non-examples.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           |                                |      |      |      |      |      |      |       |       | x     |
| CLO8        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |
| CLO9        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |
| CLO10       | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO11       | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO12       | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO13       | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO14       | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO15       | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO16       | x               |           |                                |      |      |      |      |      |      |       |       | x     |
| CLO17       | x               |           |                                |      |      |      | x    |      |      |       |       | x     |
| CLO18       | x               |           |                                |      |      |      | x    |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                           | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|-------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1<br>CLO2                  | <b>Groupoids. Semigroups. Monoids</b>           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3<br>CLO4                  | <b>Subgroups</b>                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5<br>CLO6                  | <b>Permutation groups</b>                       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7<br>CLO8                  | <b>Homomorphisms and isomorphisms of groups</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO9<br>CLO10<br>CLO11        | <b>Rings</b>                                    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO12<br>CLO13<br>CLO14       | <b>Subring</b>                                  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

|                |                                        |                                                                                        |                                                            |
|----------------|----------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO15<br>CLO16 | <b>Homomorphism of rings</b>           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO17<br>CLO18 | <b>Divisibility. Units. Associates</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which answer any **Five (05)** questions and taking at least **Two (02)** questions from each group.

**References:**

1. Israel Nathan Herstein, Topics in Algebra, John Wiley & Sons.
2. W. K. Nicholson, Introduction to Abstract Algebra, John Wiley & Sons.
3. J. B. Fraleigh, Introduction to Abstract Algebra, Pearson Education India.
4. M. Artin, Algebra, Pearson.
5. David S. Dummit, Richard M. Foote, Abstract Algebra, John Wiley and Sons Inc.

| <b>MTH 305: Fundamentals of Topology</b> |                         |                       |                          |
|------------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 305</b>              | <b>Credit Hours:</b>    | <b>Year: Third</b>    | <b>Semester:</b>         |
| <b>Course Title:</b>                     | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Fundamentals of Topology</b>          | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>                   | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                          | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

This course is about the study of elementary properties of topological spaces. Topological spaces turn up naturally in mathematical analysis, abstract algebra and geometry. A topological space is a structure that allows one to generalize concepts such as convergence, connectedness and continuity.

**Course Objectives:**

1. introduce students to the concepts of open and closed sets abstractly, not necessarily only on the real line approach.
2. introduce student to elementary properties of topological spaces and structures defined on them
3. introduce students how to generate new topologies from a given set with bases.
4. introduce student to maps between topological spaces and Homeomorphisms
5. introduce concepts of topological spaces such as connectedness and compactness
6. develop the student's ability to handle abstract ideas in topology to understand real world applications

**Course Contents:**

1. **Topological Spaces:** Definitions and examples (discrete, indiscrete, cofinite, cocountable topologies). Metric topology. Cluster point of a set. Neighbourhood system. Base and subbase. Subspace. Topological properties.

2. **Continuity:** Continuity, Sequential continuity, Uniform continuity, Homeomorphisms.
3. **Separation Axioms:** Properties of  $T_0, T_1, T_2, T_3, T_4$  spaces. Some related theorems. Completely regular spaces. Completely normal spaces.
4. **Countability of Topological Spaces:** First and second countable spaces. Separable space. Lindelof's theorems.
5. **Compactness:** Compact spaces. Concept of product spaces. Tychonoff's theorem. Locally compact spaces. Compactness in metric spaces. Totally boundedness, Lebesgue number. Equivalence of compactness, sequential compactness and Bolzano-Weierstrass property.
6. **Connectedness:** Connected spaces, totally disconnected spaces, components of space, locally and path-wise connected spaces.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1:** distinguish among open and closed sets on different topological spaces;

**CLO2:** identify precisely when a collection of subsets of a given set equipped with a topology forms a topological space;

**CLO3:** construct maps between topological spaces to understand when two topological spaces are homeomorphic;

**CLO4:** state and prove standard results regarding compact and/or connected topological spaces, and decide whether a simple unseen statement about them is true, providing a proof or counterexample as appropriate

**CLO5:** determine that a given point in a topological space is either a limit point or not for a given subset of a topological space;

**CLO6:** apply and use fixed point theorems to understand modern day applications apply theoretical concepts in topology to understand real world applications.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              | x    |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              | x    |      |      |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                             | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|---------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | <b>Topological Spaces</b>                         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | <b>Continuous functions in topological spaces</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | <b>Separation axioms</b>                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

|      |                                           |                                                                                        |                                                            |
|------|-------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO4 | <b>Countability of Topological Spaces</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5 | <b>Compactness</b>                        | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6 | <b>Connectedness</b>                      | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.  
**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. G.F. Simmons, Introduction to Topology and Modern Analysis, Krieger Publishing Company
2. S. Lipschutz, General Topology, McGraw-Hill
3. J. Kelly, General Topology, Springer-Verlag
4. J. Munkres, Topology, Prentice Hall, Inc

| <b>MTH 306: Numerical Analysis II</b> |                         |                       |                          |
|---------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 306</b>           | <b>Credit Hours:</b>    | <b>Year: Third</b>    | <b>Semester:</b>         |
| <b>Course Title:</b>                  | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Numerical Analysis II</b>          | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>                | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                       | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

This course focus on the approximation methods for solving matrix algebra, system of linear equations and system of nonlinear equations. This course also introduces different approximation methods for ordinary differential equations (ODEs), initial value problems (IVPs), boundary value problems (BVPs). It also focus on finite difference method for partial differential equations (PDEs).

**Course Objectives:**

1. To gain knowledge on several effective numerical methods for solving nonlinear equations of two or more variables.
2. This course also introduces different approximation methods for solving systems of the ordinary differential equation (ODE) and initial value problems (IVPs).
3. Students will learn different methods for solving linear and nonlinear BVPs.
4. Helps to understand the solution techniques of Parabolic, Elliptic, and Hyperbolic PDEs

**Course Contents:**

1. **Nonlinear System of Equations:** Fixed point iteration method and Newton's method for functions of several variables.
2. **IVP for ODE:** Explicit Adams-Bashforth (AB) methods, and implicit Adams-Moulton (AM) methods, predictor-corrector methods. Solution of higher-order differential equations, and systems of differential equations.
3. **Matrix Algebra:** Eigenvalues and eigenvectors, Power method

4. **BVP for ODE:** Shooting method for linear problems, Finite difference methods (FDM) for linear and nonlinear problems
5. **Parabolic PDEs (1D problems):** Solution of 1D heat equation using FDM, Explicit, Fully implicit and Crank-Nicolson Methods, Matrix formulation of the model
6. **Elliptic PDEs:** Solution of 2D Poisson's and Laplace's equations using FDM.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Explain the foundations of mathematics

**CLO2.** Interpret the basic concepts of Logic

**CLO3.** Evaluate equations and inequalities, both algebraically and graphically

**CLO4.** Formulate the Weierstrass, Cauchy's and Chebychief's inequalities

**CLO5.** Calculate different mathematical problems of complex number

**CLO6.** Distinguish among Arithmetic, Geometric and Harmonic Series

**CLO7.** Interpret the ideas of the Summation of algebraic and trigonometric series

**CLO8.** Calculate the different problems of Theory of equations.

**CLO9.** Identify the idea about of De-Moiver's Theorem

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           |                                |      |      |      |      |      |      |       |       | x     |
| CLO8        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |
| CLO9        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                         | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|-----------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1<br>CLO2                           | <b>Iterative Techniques in Matrix Algebra</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3<br>CLO4                           | <b>Nonlinear System of Equations</b>          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5<br>CLO6                           | <b>Initial value problems for ODE</b>         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                                   | <b>Boundary Value Problem for ODE</b>         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8<br>CLO9                           | <b>Finite Difference Method for PDEs</b>      | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. R.L. Burden & J.D. Faires, Numerical Analysis.
2. Eddre Suli and Devid F Mayers, Introduction to Numerical Analysis., second edition
3. K. Atkinson & W. Han Kendall Atkinson, Weimin Han, Theoretical Numerical Analysis: A Functional Analysis Framework
4. M.A. Celia & W.G. Gray, Numerical Methods for Differential Equations. L.W. Johson & R.D. Riess, Numerical Analysis.
5. M.A. Celia & W.G. Gray, Numerical Methods for Differential Equations.
6. L.W. Johson & R.D. Riess, Numerical Analysis.

**MTH 307: Mathematical Methods**

|                             |                         |                       |                          |
|-----------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 307</b> | <b>Credit Hours:</b>    | <b>Year: Third</b>    | <b>Semester:</b>         |
| <b>Course Title:</b>        | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Mathematical Methods</b> | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>      | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                             | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

This is an advanced mathematics course which is proposed to give an overview of mathematical methods widely used in physical sciences. Fourier series, Laplace transforms, Fourier transforms, Eigenvalue problems and Strum-Liouville boundary value problems will be studied. Here we focus on the application to solve real life problems. After taking this course, students will become familiar with new mathematical skills.

**Course Objectives:**

1. To understand the concept of Fourier series, its real form and complex form and enhance the real-life problem-solving skill.
2. To learn the Laplace transform, Inverse Laplace transform of various functions and its application.
3. To learn the Fourier transform of various functions and its application to solve real life boundary value problems and integral equation.
4. To learn discrete Fourier transform (DFT) and fast Fourier transform (FFT) and its applications
5. To learn the finding of eigenvalues and eigenfunctions by solving Strum-Liouville boundary value problem (S-LBVP), formation of Green's function from S-LBVP and hence the solving of S-LBVP.

**Course Contents:**

1. **Fourier Series:** Fourier series and its convergence. Fourier sine and cosine series. Properties of Fourier series. Operations on Fourier series. Complex form. Applications of Fourier series.

2. **Laplace Transforms:** Basic definitions and properties, Existence theorem. Transforms of derivatives. Relations involving integrals. Laplace transforms of periodic functions. Convolution theorem (Transforms of convolutions). Inverse transform. Calculation of inverse transforms. Use of contour integration. Applications to boundary differential equations.
3. **Fourier Transforms:** Fourier transforms. Inversion theorem. Sine and cosine transforms. Transform of derivatives, Parseval's theorem, Uncertainty principle, Transforms of rational function. Convolution theorem, circular convolutions, discrete Fourier Transform, Fast Fourier Transform, Radon transform, Applications to boundary value problems and integral equation.
4. **Eigenvalue Problems and Sturm-Liouville Boundary Value Problems:** Regular Sturm-Liouville boundary value problems. Non-homogeneous boundary value problems and the Fredholm alternative. Solution by eigenfunction expansion. Green's functions. Singular Sturm Liouville boundary value problems/Oscillation and comparison theory.

#### **Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Expand the periodic function of one variable by using Fourier series of real and complex forms.

**CLO2.** Apply Fourier series expansion of periodic function of one variable to selected physical problems.

**CLO3.** Understand the concept of Laplace transform and inverse Laplace transform of various function.

**CLO4.** Solve initial value problems and boundary value problems using Laplace transform.

**CLO5.** Calculate the Fourier transforms of simple functions and apply them to selected physical problems.

**CLO6.** find the solution of the wave, heat flow and Laplace equations using the Fourier transforms

**CLO7.** Solve integral equation.

**CLO8.** Find the eigenvalues and the corresponding eigenfunctions by solving Sturm-Liouville boundary value problems.

**CLO9.** Define the term "orthogonality" as applied to functions and recognize sets of orthogonal functions which are important in physics.

**CLO10.** Find the Green's function from Sturm-Liouville boundary value problems.

**CLO11.** Solve Sturm-Liouville boundary value problems by finding the Green's function from Sturm Liouville boundary value problems.

#### **Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |

|       |   |  |  |  |  |  |   |  |  |  |  |   |
|-------|---|--|--|--|--|--|---|--|--|--|--|---|
| CLO7  | x |  |  |  |  |  |   |  |  |  |  | x |
| CLO8  | x |  |  |  |  |  | x |  |  |  |  | x |
| CLO9  | x |  |  |  |  |  | x |  |  |  |  | x |
| CLO10 | x |  |  |  |  |  | x |  |  |  |  | x |
| CLO11 | x |  |  |  |  |  | x |  |  |  |  | x |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                                                  | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1<br>CLO2<br>CLO3          | <b>Fourier Series</b>                                                  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4<br>CLO5<br>CLO6          | <b>Laplace transforms</b>                                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7<br>CLO8<br>CLO9          | <b>Fourier transforms</b>                                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO10<br>CLO11                | <b>Eigenvalue problems and Sturm-Liouville boundary value problems</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. R.V. Churchill & J. W. Brown, Fourier Series and Boundary value problems.
2. E. Kreuzig, Advanced Engineering Mathematics.
3. M. R. Spiegel, Laplace Transforms, Schaum's Outline Series.
4. Boyce, Di Prima, Elementary Differential Equations.

| <b>MTH 308: Optimizations</b>      |                                    |                       |                                    |
|------------------------------------|------------------------------------|-----------------------|------------------------------------|
| <b>Course Code: MTH 308</b>        | <b>Credit Hours: 3.00 Hrs/Week</b> | <b>Year: Third</b>    | <b>Semester:</b>                   |
| <b>Course Title: Optimizations</b> | <b>Total Marks: 100</b>            |                       |                                    |
| <b>Course Teacher:</b>             | <b>Course Type: Theory</b>         | <b>Pre-requisite:</b> | <b>Academic Session: 2023-2026</b> |

**Rationale:**

Optimization is one of the greatest successes to emerge from operations research and management science. It is an art of finding minima or maxima of some objective function, and to some extent an art of defining the objective functions. This course will focus on the optimization techniques such as linear programming (LP), nonlinear programming (NLP) and quadratic programming (QP). This is an interdisciplinary branch of applied mathematics and natural science that uses methods like mathematical modeling, statistics, and algorithms to arrive at optimal or near optimal solutions to real life problems and closely relates to Industrial Engineering. It is a tool for solving

optimization problems. In 1947, George Dantzig developed an efficient method, the simplex algorithm, for solving linear programming problems. Since the development of the simplex algorithm, LP, NLP and QP have been used to solve optimization problems in diverse areas including but not limited to production planning, network flow, big data, banking, finance, engineering, scheduling, etc.

#### **Course Objectives:**

1. This course will mainly emphasize on the study of optimization theory, particularly on linear and non-linear optimization problems.
2. Students will obtain the theoretical understandings of several optimization problems.
3. Special focus will be given on the formulation and solution procedures of real-life problems.

#### **Course Contents:**

1. **Introduction:** Convex sets and related theorems, introduction to linear programming (LP)
2. **Formulation:** Formulation of LP problems.
3. **Solution Techniques:** Graphical solutions, Simplex method, Two -phase and Big-M simplex methods.
4. **Duality and Sensitivity:** Duality and related theorems, Dual simplex method, shadow prices and Sensitivity analysis of LP.
5. **Introductory Concepts of Nonlinear Programming (NLP):** Classification of NLP problems, Convexity of Nonlinear functions, Gradient and Hessian matrix and related theorems.
6. **Solution Techniques of Constrained NLPs:** Lagrange's Multiplier method, Kuhn-Tucker method.
7. **Solution of Quadratic Programming (QP):** Complementary pivot method, Wolfe's method etc.

#### **Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

- CLO1.** Describe the basic properties such as convex sets and related theorems;  
**CLO2.** Gather knowledge about LP, standard form, canonical form, slack variables, surplus variables, basic solutions, non-basic solutions, feasible solutions optimal solutions etc.;  
**CLO3.** Know the ways to formulate a real life problem into a mathematical problem;  
**CLO4.** Solve 2-dimensional problems by using graphical method;  
**CLO5.** solve general LP problems by using simplex method (usual simplex method, 2-phase simplex method and Big-M simplex method);  
**CLO6.** solve special type of LP by Dual simplex method;  
**CLO7.** use sensitivity analysis to study the changes in availability, conditions etc.  
**CLO8.** solve NLP problems by different optimization methods  
**CLO9.** solve QP problems by different methods.

#### **Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |

|      |   |  |   |  |  |   |   |  |   |  |  |   |
|------|---|--|---|--|--|---|---|--|---|--|--|---|
| CLO2 | x |  | x |  |  |   |   |  | x |  |  | x |
| CLO3 | x |  | x |  |  |   |   |  |   |  |  | x |
| CLO4 | x |  | x |  |  |   |   |  |   |  |  | x |
| CLO5 | x |  | x |  |  | x |   |  |   |  |  | x |
| CLO6 | x |  | x |  |  |   |   |  |   |  |  | x |
| CLO7 | x |  |   |  |  |   |   |  |   |  |  | x |
| CLO8 | x |  |   |  |  |   | x |  |   |  |  | x |
| CLO9 | x |  |   |  |  |   | x |  |   |  |  | x |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                                       | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|-------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | <b>Introduction</b>                                         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | <b>Formulation</b>                                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | <b>Solution Techniques</b>                                  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                          | <b>Duality and Sensitivity</b>                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5<br>CLO6                  | <b>Introductory Concepts of Nonlinear Programming (NLP)</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7<br>CLO8                  | <b>Solution Techniques of Constrained NLPs</b>              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO9                          | <b>Solution of Quadratic Programming (QP)</b>               | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. Wayne L. Winston, Operations Research: Applications and Algorithms, Cengage Learning.
2. A. Ravindran, Don T. Phillips, and James J. Solberg, Operations Research: Principles and Practice, Wiley.
3. F. Hiller and G. Liberman, Introduction to Operations Research, Mc Graw Hill.
4. Huseyin Topaloglu, Fundamentals of Linear Optimization: A Hopefully Uplifting Treatment, Lecture note, Cornell University.
5. Edwin K. P. Chong and Stanislaw H. Zak, An Introduction to Optimization, Wiley.

| MTH 309: Stochastic Calculus                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                         |                       |                                              |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------|----------------------------------------------|
| <b>Course Code: MTH 309</b><br><b>Course Title:</b><br><b>Stochastic Calculus</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Credit Hours:</b><br><b>3.00 Hrs/Week</b><br><b>Total Marks: 100</b> | <b>Year: Third</b>    | <b>Semester:</b>                             |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>Course Type:</b><br><b>Theory</b>                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br><b>2023-2026</b> |
| <p><b>Rationale:</b></p> <p>First course in stochastic area; moving from distribution to stochastic process. Brownian motion and its properties have been discussed and how these properties characterize a stochastic process in Black and Scholes world have been considered. Crucial for students developing into Mathematical Finance, Actuarial Science and stochastic area of Mathematical Biology for further studies. Fundamental differences between classical calculus and stochastic calculus have been explored through Ito's formula. Firsthand stochastic differential equations have been studied with stock price modelling in view; filtration and sigma-algebra structures, and information flow in stochastic world, are introduced. Foundational course for research development in stochastic environment.</p>                                                                                                                                                                                                                                                                |                                                                         |                       |                                              |
| <p><b>Course Objectives:</b></p> <ol style="list-style-type: none"> <li>1. This course will mainly emphasize on the study of stochastic calculus, departing from the deterministic one. It will help understand probability foundations, such as, measure theory concepts (<math>\sigma</math> –algebra), random variables, stochastic process, conditional expectations, etc.</li> <li>2. Students will obtain a rigorous probabilistic understanding of Brownian motion, Ito calculus, and stochastic differential equations (SDEs).</li> <li>3. Special focus will be given to the numerical solution procedures for SDEs.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                         |                       |                                              |
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li>1. <b>Introduction:</b> Sigma algebra, filtration, conditional expectation and structure of stochastic process.</li> <li>2. <b>Martingale and Brownian Motion:</b> stochastic process, construction of random walk, Brownian motion as a limit of random walk stochastic process. Distributional properties, correlation and covariance of Brownian motion stochastic process. First variation and quadratic variation of Brownian motion stochastic process. Simulation of Brownian motion paths. Martingale property of some useful Brownian motion functionals.</li> <li>3. <b>Ito's Formula and Stochastic Calculus:</b> Ito's formula (with intuitive illustrations), stochastic integral and stochastic calculus.</li> <li>4. <b>Stochastic Differential Equations (SDEs):</b> details of basic SDEs; different numerical schemes (Euler, Milstein etc.) for simulating basic SDEs.</li> <li>5. <b>SDEs and Calibration:</b> Calibrating parameters of some basic SDEs using real life (or simulated) data.</li> </ol> |                                                                         |                       |                                              |
| <p><b>Course Learning Outcomes (CLOs):</b></p> <p>After the successful completion of the course, students will be able to:</p> <p><b>CLO1.</b> Understand the concepts of sigma algebra, expectation with respect to sigma algebra, filtration, Brownian motion, martingale, Ito stochastic integral, etc. with related properties</p> <p><b>CLO2.</b> Learn Ito's formula and its implications.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                         |                       |                                              |

**CLO3.** Be able to analytically solve some specific SDEs.  
**CLO4.** Learn numerical methods for solving SDEs.  
**CLO5.** Get the idea of calibrating parameters for some basic SDEs.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                                                                 | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|---------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                                   | <b>Sigma algebra</b>                                                                  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                                   | <b>Martingale and Brownian motion stochastic process</b>                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                                   | <b>Ito's formula (with intuitive illustrations)</b>                                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                                   | <b>Ito's formula (with intuitive illustrations)</b>                                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                                   | <b>Calibrating parameters of some basic SDE's using real life (or simulated) data</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. Lawrence C. Evans, An introduction to stochastic differential equations, Lecture note, University of California, Berkeley.
2. Ubbo F. Wiersema, Brownian Motion Calculus, John, Wiley & Sons.
3. Fima C. Klebaner, Introduction to Stochastic Calculus with Applications, Imperial College Press.
4. Ovidiu Calin, An Informal Introduction to Stochastic Calculus with Applications, World Scientific.
5. Gregory F. Lawler, Stochastic Calculus: An Introduction with Applications, Lecture note..

| MTH 310: Introduction to Actuarial Mathematics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                  |                       |                                       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|-----------------------|---------------------------------------|
| <b>Course Code: MTH 310</b><br><b>Course Title:</b><br>Introduction to Actuarial Mathematics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Credit Hours:</b><br>3.00 Hrs/Week<br><b>Total Marks: 100</b> | <b>Year: Third</b>    | <b>Semester:</b>                      |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>Course Type:</b><br>Theory                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br>2023-2026 |
| <p><b>Rationale:</b></p> <p>Actuaries are the back bone for the insurance company. Without them, there is no concept of the insurance company. They work for insurance companies and predict the profitability of various customers by using the mathematical and statistical formulas. Actuaries estimate the present value cost for future uncertainty like accidents, deaths, natural disaster, disability and lawsuits. Actuaries are engaged in life insurance, retirement benefit consultancies, asset management, postretirement medical benefit, the cost of retirement benefit plans. They also involved in periodic valuation of life insurance business, pensions and other investment benefits liabilities.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                  |                       |                                       |
| <p><b>Course Objectives:</b></p> <ol style="list-style-type: none"> <li>1. Have sufficient exposure to actuarial and financial mathematics</li> <li>2. Be familiar with the role of insurance in society, basic economic theory, and the basics of how insurance and financial markets operate.</li> <li>3. Have familiarity with several of the technical tools, computer languages or software packages used by actuaries.</li> <li>4. Develop communication, leadership and teamwork skills, and understand their importance in the actuarial industry.</li> <li>5. Be able to apply this knowledge and these skills in new combinations and to new problems.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                  |                       |                                       |
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li>1. <b>Theory of Interest:</b> Interest, Simple Interest, Compound Interest, Accumulated Value, Present Value, Rate of Discount: <math>d</math>, Constant Force of Interest: <math>\delta</math>, Varying Force of Interest.</li> <li>2. <b>Annuities and its Applications:</b> Annuity-Immediate, Annuity-Due, Deferred Annuities, Continuously Payable Annuities, Perpetuities, Equations of Value. Amortization of a Debt, Outstanding Principal, Mortgages, Refinancing a Loan, Sinking Funds, Comparison of Amortization and Sinking-Fund Methods.</li> <li>3. <b>Individual Risk Models:</b> Models for Individual Claim Random Variables, Sums of Independent Random Variables, Approximations for the Distribution of the Sum, and Applications to Insurance.</li> <li>4. <b>Survival Distributions:</b> Probability for the Age-at-Death, The Survival Function, Time-Until Death for a Person Aged <math>x</math>, Curtate-Future-Lifetime, Force of Mortality.</li> <li>5. <b>Life Tables:</b> Relation of Life Table Functions to the Survival Function, Life Table Example, The Deterministic Survivorship Group, Other Life Table Functions, Assumptions for Fractional Ages, Some Analytical Laws of Mortality, Select and Ultimate Tables.</li> <li>6. <b>Life Insurance:</b> Introduction, Insurance payable at the moment of death, Insurance payable at the end of the year of death, Recursion equations, Commutation Functions.</li> </ol> |                                                                  |                       |                                       |

|                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|----------------------------------------------------------------------------------------|--------------------------------|------|------|------|------|------|------------------------------------------------------------|-------|-------|-------|
| <div>7. <b>Life Annuities:</b> Introduction, Mortality Tables, Pure Endowments, Continuous Life Annuities, Discrete Life Annuities, Life Annuities with mthly payments. Commutation Functions formula for annuities with level payments, Varying Annuities.</div> <div>8. <b>Net Premium:</b> Fully continuous premiums, Fully discrete premiums, True mthly Payment Premiums, commutation functions, and Apportionable premiums.</div> |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| <b>Course Learning Outcomes (CLOs):</b>                                                                                                                                                                                                                                                                                                                                                                                                 |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| After the successful completion of the course, students will be able to:                                                                                                                                                                                                                                                                                                                                                                |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| CLO1. Compute different types of interests which is the most important learning for a business student.                                                                                                                                                                                                                                                                                                                                 |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| CLO2. Will calculate annuities and their application in life insurance.                                                                                                                                                                                                                                                                                                                                                                 |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| CLO3. Different types of risk model will give clear idea about the formulation of policy.                                                                                                                                                                                                                                                                                                                                               |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| CLO4. Learn how to use mortality tables to calculate commutation function.                                                                                                                                                                                                                                                                                                                                                              |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| CLO5. Will learn how to calculate life annuities                                                                                                                                                                                                                                                                                                                                                                                        |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| CLO6. Learn how to use mortality tables to calculate different types of life assurances.                                                                                                                                                                                                                                                                                                                                                |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| CLO7. Net premium calculation will give advantage to find out the benefit of both the company and the policy owner.                                                                                                                                                                                                                                                                                                                     |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| <b>Mapping of CLOs with PLOs:</b>                                                                                                                                                                                                                                                                                                                                                                                                       |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| CLO/<br>PLO                                                                                                                                                                                                                                                                                                                                                                                                                             | PLO1<br>(Funda)                | PLO2(Lab)                                                                              | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9                                                       | PLO10 | PLO11 | PLO12 |
| CLO1                                                                                                                                                                                                                                                                                                                                                                                                                                    | x                              |                                                                                        | x                              |      | x    | x    | x    | x    | x                                                          | x     | x     | x     |
| CLO2                                                                                                                                                                                                                                                                                                                                                                                                                                    | x                              |                                                                                        | x                              |      |      |      |      |      | x                                                          |       |       | x     |
| CLO3                                                                                                                                                                                                                                                                                                                                                                                                                                    | x                              |                                                                                        | x                              |      |      |      |      |      |                                                            |       |       | x     |
| CLO4                                                                                                                                                                                                                                                                                                                                                                                                                                    | x                              |                                                                                        | x                              |      |      |      |      |      |                                                            |       |       | x     |
| CLO5                                                                                                                                                                                                                                                                                                                                                                                                                                    | x                              |                                                                                        | x                              |      |      | x    |      |      |                                                            |       |       | x     |
| CLO6                                                                                                                                                                                                                                                                                                                                                                                                                                    | x                              |                                                                                        | x                              |      |      |      |      |      |                                                            |       |       | x     |
| CLO7                                                                                                                                                                                                                                                                                                                                                                                                                                    | x                              |                                                                                        |                                |      |      |      |      |      |                                                            |       |       | x     |
| <b>Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning &amp; Assessment Strategy:</b>                                                                                                                                                                                                                                                                                                                                    |                                |                                                                                        |                                |      |      |      |      |      |                                                            |       |       |       |
| Course Learning Outcome (CLO)                                                                                                                                                                                                                                                                                                                                                                                                           | Topic                          | Teaching-Learning Strategies                                                           |                                |      |      |      |      |      | Assessment Strategies                                      |       |       |       |
| CLO1                                                                                                                                                                                                                                                                                                                                                                                                                                    | Theory of Interest             | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |                                |      |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO2                                                                                                                                                                                                                                                                                                                                                                                                                                    | Annuities and its Applications | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |                                |      |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO3                                                                                                                                                                                                                                                                                                                                                                                                                                    | Individual Risk Models         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |                                |      |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO4                                                                                                                                                                                                                                                                                                                                                                                                                                    | Survival Distributions         | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |                                |      |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO5                                                                                                                                                                                                                                                                                                                                                                                                                                    | Life Tables                    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |                                |      |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |

|      |                       |                                                                                        |                                                            |
|------|-----------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO6 | <b>Life Insurance</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7 | <b>Life Annuities</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8 | <b>Net Premium</b>    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**. **Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. Bowers, Gerber, Hickman, Jones Nesbitt: Actuarial Mathematics
2. Petr Zima Robert L. Brown, Mathematics of Finance, Schaum's outlines
3. Chris Ruckman, Joe Francis, Financial Mathematics: A Practical Guide for Actuaries and other Business Professionals.

| <b>MTH 350: Math Lab III (FORTRAN)</b>                |                                                 |                       |                                              |
|-------------------------------------------------------|-------------------------------------------------|-----------------------|----------------------------------------------|
| <b>Course Code: MTH 350</b>                           | <b>Credit Hours:</b>                            | <b>Year: Second</b>   | <b>Semester:</b>                             |
| <b>Course Title:</b><br><b>Math Lab III (FORTRAN)</b> | <b>3.00 Hrs/Week</b><br><b>Total Marks: 100</b> |                       |                                              |
| <b>Course Teacher:</b>                                | <b>Course Type:</b><br><b>Lab</b>               | <b>Pre-requisite:</b> | <b>Academic Session:</b><br><b>2023-2026</b> |

**Rationale:**

Fortran is a general-purpose computer programming language that is especially suited to scientific computing problems. The high-level programming language maintains popularity due to its speed. Fortran programs run at high speeds, which are only comparable to a handful of languages such as C++. FORTRAN was designed for scientists and engineers, and has dominated this field. For the past 30 years FORTRAN has been used for such projects as the design of bridges and aero plane structures, it is used for factory automation control, for storm drainage design, analysis of scientific data and so on.

**Course Objectives:**

1. Use programming operations to calculate solutions
2. Determine better and more accurate solutions
3. Perform and evaluate algebraic and trigonometric operations using built-in functions
4. Assign and manage variables
5. Manipulate vectors and matrices, use matrix indexing, and determine matrix dimensions
6. Create and evaluate x-y plots and subplots suitable for technical presentation
7. Create, test, and execute user-defined functions and sub-functions
8. Create and manipulate Structures and Arrays
9. Perform and evaluate relational and logical operations
10. Obtain and utilize user input
11. Manage and format text output

|                                                                                                                                                                                                                                                                                                                                                                                                     |                  |           |                          |                                                                                        |      |      |      |      |                                                            |       |       |       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-----------|--------------------------|----------------------------------------------------------------------------------------|------|------|------|------|------------------------------------------------------------|-------|-------|-------|
| <div>12. Perform polynomial curve-fitting, general curve fitting, and interpolation</div> <div>13. Solve non-linear systems of equations</div> <div>14. Solve numeric ODE's</div> <div>15. Perform numerical optimization</div>                                                                                                                                                                     |                  |           |                          |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>Course Contents:</b> <div><div>1. Problems Solving: Problems in the courses of Third Year BS Honours will be solved using Computer Algebra System (CAS) MATLAB.</div><div>2. Lab Assessment: Take Class Test.</div><div>3. Lab Assignments: Course instructors will provide a list of Lab assignments.</div></div>                                                                               |                  |           |                          |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>Course Learning Outcomes (CLOs):</b> <div>After the successful completion of the course, students will be able to:</div> <div><div>CLO1. Understanding MATHEMATICA/ MATLAB/ FORTRAN/ C/ Mapple.</div><div>CLO2. Apply any of the programing language in higher study.</div><div>CLO3. Solve real life problem using the programing language.</div></div>                                         |                  |           |                          |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>Mapping of CLOs with PLOs:</b>                                                                                                                                                                                                                                                                                                                                                                   |                  |           |                          |                                                                                        |      |      |      |      |                                                            |       |       |       |
| CLO/ PLO                                                                                                                                                                                                                                                                                                                                                                                            | PLO1 (Funda)     | PLO2(Lab) | PLO3 (Critical Thinking) | PLO4                                                                                   | PLO5 | PLO6 | PLO7 | PLO8 | PLO9                                                       | PLO10 | PLO11 | PLO12 |
| CLO1                                                                                                                                                                                                                                                                                                                                                                                                | x                |           | x                        |                                                                                        | x    | x    | x    | x    | x                                                          | x     | x     | x     |
| CLO2                                                                                                                                                                                                                                                                                                                                                                                                | x                |           | x                        |                                                                                        |      |      |      |      | x                                                          |       |       | x     |
| CLO3                                                                                                                                                                                                                                                                                                                                                                                                | x                |           | x                        |                                                                                        |      |      |      |      |                                                            |       |       | x     |
| <b>Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning &amp; Assessment Strategy:</b>                                                                                                                                                                                                                                                                                                |                  |           |                          |                                                                                        |      |      |      |      |                                                            |       |       |       |
| Course Learning Outcome (CLO)                                                                                                                                                                                                                                                                                                                                                                       | Topic            |           |                          | Teaching-Learning Strategies                                                           |      |      |      |      | Assessment Strategies                                      |       |       |       |
| CLO1                                                                                                                                                                                                                                                                                                                                                                                                | Problems Solving |           |                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO2                                                                                                                                                                                                                                                                                                                                                                                                | Lab Assessment   |           |                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| CLO3                                                                                                                                                                                                                                                                                                                                                                                                | Lab Assignments  |           |                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      |      | Class test and final written examination, assignment, viva |       |       |       |
| <b>Evaluation:</b> Internal Assessment: <b>40 Marks</b> , Final Examination (Lab 3 Hours): <b>60 Marks</b> . <div>Four (04) questions of equal value will be set, of which <b>All Questions</b> are to be answered.</div>                                                                                                                                                                           |                  |           |                          |                                                                                        |      |      |      |      |                                                            |       |       |       |
| <b>References:</b> <div><div>1. Introduction to FORTRAN 90/95 for Scientists and Engineers by Stephen J. Chapman.</div><div>2. Modern FORTRAN Explained by Michael Metcalf, John Reid and Malcolm Cohen.</div><div>3. Introduction to Programming with FORTRAN by Ian Chivers and Jane Sleightholme.</div><div>4. Numerical Methods of Mathematics Implemented in FORTRAN by S.K. Bose.</div></div> |                  |           |                          |                                                                                        |      |      |      |      |                                                            |       |       |       |

**MTH 399: Viva Voce**

**Credits: 2**

**Viva Voce on courses taught in the Third Year.**

## Curriculum for Four-Year BS Honours Program

Department of Mathematics

University of Dhaka



### List of Departmental Courses for Fourth Year

(35 Credits)

(Effective for 2023-2024 and onwards)

#### MTH 401–MTH 406 (18 Credits)

| Course No.                                                                                                        | Course Name                               | Credits  |
|-------------------------------------------------------------------------------------------------------------------|-------------------------------------------|----------|
| MTH 401                                                                                                           | Introduction to Functional Analysis       | 3 credit |
| MTH 402                                                                                                           | Introduction to Measure Theory            | 3 credit |
| MTH 403                                                                                                           | Partial Differential Equations            | 3 credit |
| MTH 404                                                                                                           | Differential Geometry and Tensor Calculus | 3 credit |
| MTH 405                                                                                                           | Mechanics                                 | 3 credit |
| MTH 406                                                                                                           | Hydrodynamics and Fluid Dynamics          | 3 credit |
| <b>Courses MTH 411–MTH 420 to be offered by the Academic Committee (Three courses has to be taken: 9 Credits)</b> |                                           |          |
| MTH 411                                                                                                           | Combinatorics                             | 3 credit |
| MTH 412                                                                                                           | Fuzzy Mathematics                         | 3 credit |
| MTH 413                                                                                                           | Population Dynamics                       | 3 credit |
| MTH 414                                                                                                           | Scientific Computing and simulations      | 3 credit |
| MTH 415                                                                                                           | Introduction to Mathematical Finance      | 3 credit |
| MTH 416                                                                                                           | Stochastic Optimization                   | 3 credit |
| MTH 420                                                                                                           | Special Topics                            | 3 credit |
|                                                                                                                   |                                           |          |
| MTH 450                                                                                                           | Math Lab IV (MATLAB)                      | 3 credit |
| MTH 490                                                                                                           | Honours Project                           | 3 credit |
| MTH 499                                                                                                           | Viva Voce                                 | 2 credit |

| <b>MTH 401: Introduction to Functional Analysis</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                  |                       |                                       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|-----------------------|---------------------------------------|
| <b>Course Code: MTH 401</b><br><b>Course Title:</b><br>Introduction to Functional Analysis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>Credit Hours:</b><br>3.00 Hrs/Week<br><b>Total Marks: 100</b> | <b>Year: Fourth</b>   | <b>Semester:</b>                      |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Course Type:</b><br>Theory                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br>2023-2026 |
| <p><b>Rationale:</b></p> <p>This course will cover the foundations of functional analysis in the context of topological linear spaces and normed linear spaces. It will start with a review of the theory of general linear spaces. The linear analysis on Hilbert spaces with its rich geometrical structures will be studied with normed linear spaces. Uniform Boundedness Principle, Open Mapping Theorem and Closed Graph Theorem will be presented and several applications will be analyzed. The important notion of duality will be developed in Banach and Hilbert spaces. Bounded and unbounded self-adjoint operators in Hilbert spaces will be analyzed. Further, Banach Fixed point theorem with applications, Schauder fixed point theorem, Frechet derivative and Newton's method for nonlinear operators will be introduced.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                  |                       |                                       |
| <p><b>Course Objectives:</b></p> <p>This course introduces students to the basic knowledge of linear functional analysis, an important branch of modern analysis. This is a course on functional analysis for mathematics students. It aims to study normed linear spaces and some of the linear operators between them and give some applications of their use. The normed linear spaces which are complete metric spaces are especially important.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                  |                       |                                       |
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li><b>1. Review of General Linear (Vector) Spaces:</b> Linear mappings, linear operators, elementary properties of linear operators, linear operators in finite dimensional spaces, linear functional, basis and its dual on finite dimensional space, Zorn's lemma, extension of linear functions, sublinear functional.</li> <li><b>2. Inner Product and Norm (on a vector space over <math>\mathbb{R}</math>):</b> Definitions and examples, Cauchy-Schwarz inequality, norm derived from inner product, Parallelogram law, metric derived from a norm, inner product space, orthogonality, Bessel's inequality.</li> <li><b>3. Normed Linear Spaces:</b> Sequence space, separability, Riesz's lemma, boundedness and continuity, Quotient space, spaces of bounded linear operators.</li> <li><b>4. Banach Spaces:</b> Open mapping theorem, closed graph theorem, and their applications, Baire's category theorem, Uniform boundedness principle, normed conjugate of a NLS (Hahn-Banach theorem). Fixed point theorems: Contraction mapping, Banach fixed point theorem, Schauder fixed point theorem and applications of fixed-point theorems.</li> <li><b>5. Hilbert Spaces:</b> Basic properties, Riesz representation theorem, adjoint of a linear operator.</li> </ol> |                                                                  |                       |                                       |
| <p><b>Course Learning Outcomes (CLOs):</b></p> <p>After the successful completion of the course, students will be able to:</p> <p><b>CLO1.</b> Familiarity with the main, big theorems of functional analysis.</p> <p><b>CLO2.</b> Learn the fundamental concepts of Topological Linear Spaces and study of the properties of bounded linear maps between topological linear spaces of various kinds.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                  |                       |                                       |

**CLO3.** Ability to use duality in various contexts and theoretical results from the course in concrete situations.

**CLO4.** Capacity to work with families of applications appearing in the course, particularly specific calculations needed in the context of famous theorem.

**CLO5.** Be able to produce examples and counter examples illustrating the mathematical concepts presented in the course.

**CLO6.** Understand the statements and proofs of important theorems and be able to explain the key steps in proofs, sometimes with variation.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              | x    | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              | x    |      | x    |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              | x    |      | x    |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              | x    |      | x    |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              | x    |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              | x    |      | x    |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                                                          | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                                   | <b>Review of General Linear (Vector) spaces</b>                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                                   | <b>Inner product and norm (on a vector space over <math>\mathbb{R}</math>)</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                                   | <b>Normed linear spaces</b>                                                    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                                   | <b>Banach spaces</b>                                                           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5<br>CLO6                           | <b>Hilbert spaces</b>                                                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. E. Taylor, Introduction to Functional Analysis, Wiley
2. E. Kreyszig, Introduction to Functional Analysis with Applications, Wiley
3. J. Maddox, Elements of Functional Analysis, Cambridge University Press
4. B. Rynne, M. A. Youngson, Linear Functional Analysis, Springer
5. M. Schechter, Principles of Functional Analysis, American Mathematical Society

| MTH 402: Introduction to Measure Theory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                    |                |                                |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|----------------|--------------------------------|
| Course Code: MTH 402<br>Course Title:<br>Introduction to Measure Theory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Credit Hours:<br>3.00 Hrs/Week<br>Total Marks: 100 | Year: Fourth   | Semester:                      |
| Course Teacher:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Course Type:<br>Theory                             | Pre-requisite: | Academic Session:<br>2023-2026 |
| <b>Rationale:</b><br><br>This course is an introduction to measure and integration theory, and their applications to the approximation of real valued functions. The course focuses on the generalization of idea of length, area, and volume of a subset of Euclidean space to the so-called measure of a set. The idea of measure broadens the class of integrable functions compared to the Riemann integrable functions. Then we study convergence for sequences of integrable functions. The course is designed to provide the elementary introduction needed for an advanced abstract course on Measure and Integration.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                    |                |                                |
| <b>Course Objectives:</b><br><br>The main objective of the course are generalization of idea of length, area, and volume of a subset of Euclidean space to measure of a set, exploiting the idea of measure to enrich the class of integrable functions from the class of Riemann integrable functions, and to discuss the properties of measurable functions and integration on $\mathbb{R}^n$ .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                    |                |                                |
| <b>Course Contents:</b><br><br><ol style="list-style-type: none"> <li><b>Concepts of Measure:</b> Sets and extended real number, Outer Measure and its properties, <math>\sigma</math>-algebra, Measures, Sets of measure zero, example of not measurable sets, and complete measure space.</li> <li><b>Lebesgue Measures on <math>\mathbb{R}^n</math>:</b> Lebesgue outer measure, Outer measures on rectangles. Caratheodory measurability, Null sets and completeness, Translational invariance of Lebesgue measure, Lebesgue measure under linear transformation, Borel sets, Borel regularity.</li> <li><b>Measurable Function:</b> Measurability of functions, Measurability of real (extended real) valued functions, Convergence in measure, pointwise convergence of sequence of measurable functions, Simple functions, Properties of functions that holds almost everywhere.</li> <li><b>Integral:</b> Step functions, Simple functions, Positive functions, Lebesgue integrals of real valued functions and its properties, Comparison between Lebesgue and Riemann integrals. Absolute continuity, Monotone convergence theorem. Limitations of Lebesgue integration, Lebesgue dominated convergence theorem, summation and integration.</li> <li><b>Differentiation and Integration:</b> Differentiation of monotone functions, function of bounded variation, differentiation of an integral.</li> </ol> |                                                    |                |                                |
| <b>Course Learning Outcomes (CLOs):</b><br><br>After the successful completion of the course, students will be able to:<br><br><b>CLO1.</b> Students will be able to apply the knowledge of basic analysis<br><b>CLO2.</b> Students will extend their knowledge of analysis further.<br><b>CLO3.</b> student will learn Outer measure and Measure as a generalization of volume of a set in Euclidian space                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                    |                |                                |

- CLO4.** Student will be able to integrate wider class of functions.
- CLO5.** Student will learn properties of Lebasque integration.
- CLO6.** Student will learn limit integration theorems that are very important in applications of analysis.
- CLO7.** Student will be able to differentiate functions defined by integral.
- CLO8.** Student will be able apply measure theoretic results in learning other branches of mathematics, Modeling and Engineering.
- CLO9.** This course will particularly enhance analytical and critical thinking ability.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              | x    |      | x    | x    | x    |      | x     |       | x     |
| CLO2        | x               |           | x                              | x    |      | x    | x    | x    | x    | x     |       | x     |
| CLO3        | x               |           | x                              | x    |      |      | x    | x    |      |       |       | x     |
| CLO4        | x               |           | x                              | x    |      |      | x    | x    |      | x     |       | x     |
| CLO5        | x               |           | x                              |      |      |      | x    |      |      |       |       | x     |
| CLO6        | x               |           | x                              | x    |      | x    | x    |      | x    |       |       | x     |
| CLO7        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO8        |                 |           | x                              |      |      | x    | x    | x    | x    | x     |       | x     |
| CLO9        | x               |           | x                              | x    | x    | x    | x    | x    | x    | x     |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                                                                                                                                                                                                                          | Teaching-Learning<br>Strategies       | Assessment<br>Strategies     |
|----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|------------------------------|
| CLO1                                   | the entire content of the course.                                                                                                                                                                                                              | Lecture/ home<br>work/giving feedback | Class Test and<br>Final exam |
| CLO2                                   | Lebesgue outer measure, Outer measures on rectangles. Caratheodory measurability, Null sets and completeness, Translational invariance of Lebesgue measure, Lebesgue measure under linear transformation, Borel sets, Borel regularity.        | Lecture/ home<br>work/giving feedback | Class Test and<br>Final exam |
| CLO3                                   | Sets and extended real number, Outer Measure and its properties, $\sigma$ -algebra, Measures, Sets of measure zero, example of not measurable sets, and complete measure space.                                                                | Lecture/ home<br>work/giving feedback | Class Test and<br>Final exam |
| CLO4                                   | Measurability of functions, Measurability of real (extended real) valued functions, Convergence in measure, pointwise convergence of sequence of measurable functions, Simple functions, Properties of functions that holds almost everywhere. | Lecture/ home<br>work/giving feedback | Class Test and<br>Final exam |
| CLO5                                   | Step functions, Simple functions, Positive functions, Lebesgue integrals of real valued functions and its properties, Comparison between Lebesgue and Riemann integrals                                                                        | Lecture/ home<br>work/giving feedback | Class Test and<br>Final exam |
| CLO6                                   | Monotone convergence theorem. Limitations of Lebesgue integration, Lebesgue dominated convergence theorem, summation and integration.                                                                                                          | Lecture/ home<br>work/giving feedback | Class Test and<br>Final exam |
| CLO7                                   | Differentiation of monotone functions, function of bounded variation, differentiation of an integral                                                                                                                                           | Lecture/ home<br>work/giving feedback | Class Test and<br>Final exam |
| CLO8                                   | This part of learning will be ensured by picking examples from field of differential equations, Modeling and engineering.                                                                                                                      | Lecture/ home<br>work/giving feedback | Class Test and<br>Final exam |
| CLO9                                   | This CLO will be achieved from the study of intense logically challenging contents that is abstract in nature.                                                                                                                                 | Lecture/ home<br>work/giving feedback | Class Test and<br>Final exam |

**Evaluation:** In-course Assessment: **30 Marks.** Final Examination (Theory, 3 Hours): **70 Marks.**

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. Piermarco Cannarsa and Teresa D'Aprile, Introduction to Measure Theory and Functional Analysis, University text, Springer
2. H. L. Royden, Real Analysis, Pearson
3. P.R. Halmos, Measure Theory, Springer
4. Robert Bartle, The elements of integration and Lebesgue measure, Wiley Classics Library
5. Gerald B. Folland, Real Analysis, Modern Techniques and Their Application, second edition, A Wiley-Interscience Series of Text, Monographs, and Tracts.

**MTH 403: Partial Differential Equations**

|                                       |                         |                       |                          |
|---------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 403</b>           | <b>Credit Hours:</b>    | <b>Year: Fourth</b>   | <b>Semester:</b>         |
| <b>Course Title:</b>                  | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Partial Differential Equations</b> | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>                | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                       | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

Partial differential equations (PDE) is an important branch of Science. It has many applications in various physical and engineering problems. The idea of the course is to give a solid introduction to PDE for advanced undergraduate students. We require only advanced calculus. The course goes quite rapidly through a lot of material, but our focus is linear second order uniformly elliptic, parabolic and hyperbolic equations. In this course mainly we attempt to give some ideas about first order and second order linear PDEs. A few Nonlinear PDE is discussed shortly. The method of solving first-order and second order equations are illustrated taking many examples.

**Course Objectives:**

1. State the heat, wave, Laplace, and Poisson equations and explain their physical origins, basic existence, uniqueness and continuous dependence of initial and boundary conditions.
2. Identify and classify linear PDEs.
3. Solve simple first order equations using the method of characteristics;
4. Identify homogeneous PDEs and evolution equations.
5. Solve the wave equation using d'Alembert's formula.
6. Solve wave equation by separating variables and Fourier series.
7. Solve the heat, wave, Laplace, and Poisson equations using separation of variables and apply boundary conditions.
8. Solve PDEs using Fourier integrals and transforms.

**Course Contents:**

- 1. Introduction:** Preliminaries, Classification, Differential operators and the superposition principle, Differential equations as mathematical models, Associated conditions, Simple examples.
- 2. First Order Equations:** Definition of PDEs of First Order Quasi-linear PDEs; Solving PDEs of First Order: The method of characteristics; The existence and uniqueness theorem; The Lagrange method; Conservation laws and shock waves; The eikonal equation; General nonlinear equations.
- 3. Second Order Equations:** Definition of General PDE, Classifications of Second Order PDEs as Parabolic, Hyperbolic, and Elliptic Equations; Canonical form of hyperbolic/ parabolic / elliptic equations.
- 4. The One Dimensional Wave Equation:** Introduction, Canonical form and general solution, The Cauchy problem and d'Alembert's formula, Fourier Transform methods, Domain of dependence and region of influence, The Cauchy problem for the nonhomogeneous wave equation, Two-Dimensional Wave Equation.
- 5. The Heat Equation:** The Cauchy Problem and initial conditions, The weak maximum principle, solutions on bounded intervals, on the real line and on the half line, the nonhomogeneous heat equation, The energy method and uniqueness.
- 6. Elliptic Equations:** Introduction, The maximum principle, Green's identities, Separation of variables for elliptic problems, Poisson's formula, Dirichlet and Neumann Problems, Green's functions and integral representations in a plane.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1:** Explain the notion of partial differential equations, explains the meaning of solution of a partial differential equation, Discuss Existence, Uniqueness and wellposedness of solutions of PDEs

**CLO2:** Solve first-order partial differential equations, solve simple first order equations using the method of characteristics; classify second order equations

**CLO3:** Explain Conservation laws and shock waves; The eikonal equation; General nonlinear equations.

**CLO4:** Classify second order linear partial differential equations

**CLO5:** Present Techniques to reduce second order partial differential equations to standard form and solve the problems

**CLO6:** Learn basics of Fourier analysis

**CLO7:** Find solution techniques for second order hyperbolic PDEs, solve simple initial and boundary value problems using e.g. d'Alembert's solution; formula, separation of variables, Fourier series expansion, Fourier transform methods

**CLO8:** discuss solutions techniques for parabolic PDEs, formulate maximum principles for various equations and derive consequences

**CLO9:** Interpret Solutions techniques for Laplace and Poissons equations

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     |       |
| CLO2        | x               |           | x                              | x    |      | x    |      |      | x    |       |       |       |

|      |   |  |   |   |   |   |  |  |  |   |  |   |
|------|---|--|---|---|---|---|--|--|--|---|--|---|
| CLO3 | x |  | x |   |   | x |  |  |  |   |  |   |
| CLO4 | x |  | x |   | x | x |  |  |  |   |  |   |
| CLO5 | x |  | x | x |   | x |  |  |  |   |  | x |
| CLO6 | x |  | x |   |   | x |  |  |  | x |  | x |
| CLO7 | x |  | x |   |   | x |  |  |  |   |  |   |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                                                                                                              | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | Introduction to PDE and basic concepts, Solutions techniques for first order PDEs using Lagrange method, method of characteristics | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | Solutions techniques, Interpretation of solutions and applications in physics                                                      | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | Conservation laws and shock waves; The eikonal equation, existence, uniqueness and wellposedness of solutions                      | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                          | Classification of 2 <sup>nd</sup> order PDEs                                                                                       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                          | Canonical form for 2 <sup>nd</sup> order PDEs and solutions                                                                        | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                          | Fourier analysis                                                                                                                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                          | Wave equations                                                                                                                     | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. Peter V. O'Neil, Beginning Partial Differential Equations, John Wiley & Sons.
2. Walter A. Strauss, Partial Differential Equations: An Introduction, John Wiley & Sons.
3. T. Hillen, I E Leonard and H. Van Roessel, Partial Differential Equations: Theory and Completely Solved Problems, Friesen Press.
4. Nakhle H. Asmar, Partial Differential Equations and Boundary Value Problems with Fourier Series, Dover Books on Mathematics.

| MTH 404: Differential Geometry and Tensor Calculus |                  |              |           |
|----------------------------------------------------|------------------|--------------|-----------|
| Course Code: MTH 404                               | Credit Hours:    | Year: Fourth | Semester: |
| Course Title:                                      | 3.00 Hrs/Week    |              |           |
| Differential Geometry and Tensor Calculus          | Total Marks: 100 |              |           |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                       |                                       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------|---------------------------------------|
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Course Type:</b><br>Theory | <b>Pre-requisite:</b> | <b>Academic Session:</b><br>2023-2026 |
| <p><b>Rationale:</b></p> <p>Differential geometry is based on three dimensional basic vectors geometry with calculus. Tensor calculus forms an essential part of the mathematical background required to applied mathematicians, physicists, space scientists and engineers. It's widely used in many branches of pure and applied mathematics. Indeed, the algebraic properties of tensors form the subject matter of linear algebra, while their differential properties that of differential geometry. Understanding of this Course will precede students to learn other areas of mathematics such as Geometry of Differential Manifolds, General Theory of Relativity, Cosmology, Riemannian Geometry etc.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                       |                                       |
| <p><b>Course Objectives:</b></p> <ol style="list-style-type: none"> <li>1. To give knowledge on mathematical concepts of space curve and surfaces, this course is very much useful.</li> <li>2. Students will know the concepts of helices, tangent, normal, bi-normal, involutes and evolutes.</li> <li>3. Students will learn about the fundamental forms, Gaussian and normal Curvature, Geodesics etc. on mathematical concepts of surface.</li> <li>4. Student will have knowledge on Christoffel's symbols and their applications, Riemann Christoffel tensor and the Ricci tensor.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                       |                                       |
| <p><b>Course Contents:</b></p> <p style="text-align: center;"><b>Group A: Differential Geometry</b></p> <ol style="list-style-type: none"> <li>1. <b>Curves in Space:</b> Vector functions of one variable, Analytic representation of curves, Arc length, Space curves, unit tangent to a space curve, equation of a tangent, normal and binormal line to a curve, Osculating plane (or Plane of curvature).</li> <li>2. <b>Serret-Frenet's Formulae:</b> Curvature, Torsion, Helices, Spherical Indicatrix of tangent, etc. Involute, Evolute, Bertrand curves.</li> <li>3. <b>Vector Functions of Two Variables:</b> Tangent and normal plane to the surface. Principal normal, binormal and Fundamental planes, theorems on curvature and torsion.</li> <li>4. <b>Elementary Theory of Surfaces:</b> Analytic representation of surfaces, Monge's form of the surface, First fundamental form or metric, geometrical interpretation of metric, properties of metric, angle between any two directions and parametric curves, condition of orthogonality of parametric curves, elements of area, unit surface normal, Normal, tangent plane. \</li> <li>5. <b>Second Fundamental Form:</b> Meusnier's theorem, principal direction and curvature, Rodrigues's formula, Euler's theorem, a geometrical interpretation of asymptotic and curvature lines, Mean and Gaussian Curvature, Elliptic, hyperbolic and parabolic points, Dupin Indicatrix, Third Fundamental form, Theorem of Beltrami-Enneper. The equation of Gauss-Weingarten.</li> </ol> |                               |                       |                                       |

## Group B: Tensor Calculus

6. **The Tensor Concept:** Covariant and Contravariant tensors, Cartesian tensors, symmetric and skew-symmetric tensors. Christoffel's symbols, Transformation laws of Christoffel's symbols and their applications.
7. **Covariant Differentiation:** Covariant derivatives, The Riemann-Christoffel tensor and the Ricci tensor, the zero tensor, Intrinsic derivative, Bianchi identity, Covariant curvature tensor, Flat Space.

### **Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Apply Serret-Frenet's Formulae to solve various types of problems.

**CLO2.** Earn basic knowledge about tangent, normal, binormal and different types of planes, Curvature, Torsion.

**CLO3.** Solve to find tangent, normal, bi-normal and their lines, curvature and torsion of a space curve.

**CLO4.** Gather knowledge about Spherical indicatrix of tangent, normal, binormal, curvature and torsion.

**CLO5.** Illustrate curves of involutes and evolutes and Bertrand curves.

**CLO6.** Know how to find different types of fundamental forms of surfaces.

**CLO7.** Know how to find the angle of two directions of surfaces.

**CLO8.** Apply the concepts of element of area, surface normal, normal, tangent plane, fundamental magnitudes to find Mean curvature and Gaussian Curvature.

**CLO9.** Apply the concepts of tensor calculus to do various types of problem solution in Theory of Relativity Cosmology.

### **Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              | x    | x    |      | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              | x    | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO3        | x               |           | x                              | x    | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO4        | x               |           | x                              | x    | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO5        | x               |           | x                              | x    |      |      |      | x    | x    |       | x     | x     |
| CLO6        | x               |           | x                              | x    |      |      |      | x    | x    | x     | x     | x     |
| CLO7        | x               |           | x                              | x    | x    | x    |      | x    | x    | x     | x     | x     |
| CLO8        | x               |           | x                              | x    | x    |      |      | x    | x    | x     | x     | x     |
| CLO9        | x               | x         | x                              | x    | x    | x    | x    | x    | x    | x     | x     | x     |

### **Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                                                   | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1<br>CLO2                           | Space curve, tangent, normal, binormal, plane, Serret-Frenet's Formulae | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

|              |                                                                                                                                                                        |                                                                                        |                                                            |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO3<br>CLO4 | Tangent, normal, bi-normal lines, Spherical Indicatrix of Tangent, Normal, Binormal, Curvature, Torsion.                                                               | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5         | Involutes and Evolutes and Bertrand curves.                                                                                                                            | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6<br>CLO7 | Fundamental forms or metric of surfaces, angle of two directions and parametric curves, condition of orthogonality of two directions and parametric curves on surfaces | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8         | Element of area, surface normal, normal, tangent plane, fundamental magnitudes to find Mean Curvature and Gaussian Curvature.                                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO9         | Christoffel's symbols, The Riemann-Christoffel tensor, Ricci tensor, Covariant curvature tensor, Flat Space.                                                           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which answer any **Five (05)** questions and taking at least **Two (02)** questions from each group.

**References:**

1. C. E. Weatherburn, Differential Geometry of Three Dimensions, Cambridge University Press, London.
2. D. J. Struik, Lectures on Classical Differential Geometry, Addison-Wesley Publishing Company, Inc. USA.
3. M. M. Lipschutz, Theory and Problems of Differential Geometry, McGraw-Hill Book Company, New York.
4. N. Srivastava, Tensor Calculus Theory and Problems, University Press Limited, India.
5. Barry Spain, Tensor Calculus a Concise Course, Dover Publications Inc. Mineola New York.

| MTH 405: Mechanics          |                         |                       |                          |
|-----------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 405</b> | <b>Credit Hours:</b>    | <b>Year: Fourth</b>   | <b>Semester:</b>         |
| <b>Course Title:</b>        | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Mechanics</b>            | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>      | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                             | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

Mechanics describes the behavior of a body, in either a beginning state of rest or of motion, subjected to the action of forces. Applied mechanics, bridges the gap between physical theory and its application to technology. It is used in many fields of engineering, especially mechanical engineering and civil engineering. In this context, it is commonly referred to as Engineering Mechanics. Much of modern engineering mechanics is based on Isaac Newton's laws of motion

while the modern practice of their application can be traced back to Stephen Timoshenko, who is said to be the father of modern engineering mechanics.

**Course Objectives:**

Resultant force and couple corresponding to any base point of a system of coplanar forces with general conditions of equilibrium of a system of coplanar forces. Centre of gravity and formulate for the centre of gravity by integration. Stable and unstable equilibriums with examples. S.H.M. (Periodic time, Amplitude & Frequency) as well as compounding of two simple harmonic motions of the same period and in the same straight line. Motion where the accelerations are parallel to fixed axes with tangential and normal accelerations. About apse, apsidal distance and apsidal angle and some important theorems related to the central force. Accelerations of a particle in terms of polar coordinates and accelerations of a particle in terms of cylindrical coordinates.

**Course Contents:**

**Group A: Statics**

1. **Reduction and Equilibrium of Coplanar Forces:** Reduction of coplanar forces, Equilibrium of three coplanar forces, Resultant force and couple, General condition of equilibrium and related topics.
2. **The Centre of Gravity of a Body:** Definition of the Centre of gravity, General formulae for the determination of the Centre of gravity, Formulae for the Centre of gravity of an Arc and any plane area,
3. **Stable and Unstable Equilibriums:** Definitions of stable and unstable equilibriums with examples, some important theorems involving stable and unstable equilibriums.

**Group B: Dynamics**

4. **Motion of a Particle in a Straight Line:** Some Important theorems related to Simple Harmonic Motion (Periodic time, Amplitude and Frequency), Motion of a particle towards the earth from a point outside of it.
5. **Motion of a Particle in a Plane:** Motion where the accelerations are parallel to fixed axe, Motion in a plane referred to polar coordinates, Velocities and accelerations of a particle along and perpendicular to the radius vector to it from a fixed origin, Tangential and normal accelerations.
6. **Central Forces:** Definitions of central force and central orbit, Apse, Apsidal distance and apsidal angle, some important theorems related to the central force, Kepler's Laws.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

- CLO1.** Students have to learn resultant force and couple corresponding to any base point of a system of coplanar forces with general conditions of equilibrium of a system of coplanar forces.
- CLO2.** Further, general formulae for the determination of the centre of gravity and formulate for the centre of gravity by integration.
- CLO3.** Definitions of stable and unstable equilibriums with examples.

**CLO4.** They have to learn some important theorems related to S.H.M. (Periodic time, Amplitude & Frequency) as well as compounding of two simple harmonic motions of the same period and in the same straight line.

**CLO5.** Therefore, motion where the accelerations are parallel to fixed axes with tangential and normal accelerations.

**CLO6.** Learning about apse, apsidal distance and apsidal angle and some important theorems related to the central force.

**CLO7.** Accelerations of a particle in terms of polar coordinates and accelerations of a particle in terms of cylindrical coordinates.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           |                                |      |      |      |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                               | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|-----------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                                   | <b>Reduction and Equilibrium of coplanar forces</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                                   | <b>The Centre of Gravity of a Body</b>              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                                   | <b>Stable and Unstable Equilibriums</b>             | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                                   | <b>Motion of a Particle in a Straight line</b>      | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                                   | <b>Motion of a Particle in a Plane</b>              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                                   | <b>Central Forces</b>                               | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which answer any **Five (05)** questions and taking at least **Two (02)** questions from each group.

**References:**

1. **S. L. Loney:** Statics and Analytical Dynamics of a Particle, Publisher Arihant Publications
2. **L.A. Pars:** Introduction to Dynamics, Publisher, New Age International

| MTH 406: Hydrodynamics and Fluid Dynamics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                  |                       |                                       |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|-----------------------|---------------------------------------|
| <b>Course Code: MTH 406</b><br><b>Course Title:</b><br>Hydrodynamics and Fluid Dynamics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>Credit Hours:</b><br>3.00 Hrs/Week<br><b>Total Marks: 100</b> | <b>Year: Fourth</b>   | <b>Semester:</b>                      |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>Course Type:</b><br>Theory                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br>2023-2026 |
| <p><b>Rationale:</b></p> <p>The course deals with theoretical and practical aspects of hydrodynamics and fluid dynamics. The various topics covered are: Reynolds Transport Theorem, conservation of mass, momentum and energy, the development of the Navier-Stokes' equation, ideal and potential flows, vorticity, hydrodynamic forces in potential flow. Some of the vital topics covered are boundary layer concept, governing equations, incompressible flows, compressible flows, high speed flows, internal flow, external flow, dimensional analysis, and introduction to computational fluid dynamics.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                  |                       |                                       |
| <p><b>Course Objectives:</b></p> <ol style="list-style-type: none"> <li>1. To understand the concept of fluid and to be able to explain the properties of fluid.</li> <li>2. To understand the hydrostatic forces acting on a solid surface immersed in liquid and to be able to calculate them in a specific situation.</li> <li>3. To understand the basic equations of the conservation laws (continuity equation, Euler's equation and Bernoulli's theorem, momentum theorem) and to be able to apply them in a specific problem.</li> <li>4. To understand the concept of dimensional analysis and to be able to apply it in a specific situation.</li> <li>5. To understand about the Navier-Stokes equation, steady and unsteady laminar flow.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                  |                       |                                       |
| <p><b>Course Contents:</b></p> <p style="text-align: center;"><b>Group A: Hydrodynamics</b></p> <ol style="list-style-type: none"> <li>1. <b>Preliminaries:</b> Velocity and acceleration of fluid particles; relation between local and individual rates; steady and unsteady flows; uniform and non-uniform flows; stream lines; path lines; vortex lines; velocity potential; Rotational and irrotational flows.</li> <li>2. <b>Continuous Motion:</b> Equations of continuity; equations of continuity in spherical and cylindrical polar co-ordinates; boundary surfaces. Euler's equation of motion, conservative field of force; motion under conservative body force; vorticity equations (Helmholtz's vorticity equation); Bernoulli's equations and its application.</li> <li>3. <b>Two-Dimensional Flow:</b> Motion in two-dimensions; stream function, physical meaning of stream function; velocity in polar-coordinates; relation between stream function and velocity; circulation and vorticity; relation between circulation and vorticity; Kelvin's circulation theorem.</li> <li>4. <b>Circle Theorem and Complex Dynamics:</b> The circle's theorem; motion of a circular cylinder; pressure at points on a circular cylinder; application of circle theorem. Blasius</li> </ol> |                                                                  |                       |                                       |

theorem; Sources, sinks and doublets; complex potential and complex velocity; stagnation points.

### Group B: Fluid Dynamics

5. **Fundamentals of Fluid Dynamics:** Definition of fluid dynamics, viscosity; Newtonian and non-Newtonian fluids; body and surface forces; stress and rate of strain and their relation; Newton's law of viscosity.
6. **Navier-Stokes Equation of Motion:** Navier-Stokes equations of motion of a viscous fluid; equation of state for perfect fluid; conservation of energy; conservation of mass.
7. **Dimensional Analysis:** Dimensional homogeneity; dynamical similarity; Reynolds principle of similarity and significance; Reynolds/ Prandtl/ Grashof/ Rayleigh/ Richardson's/ Eckert/ Peclet/ Nusselt numbers; Some dimensionless coefficients employed in the study of viscous fluid flow-skin-friction coefficient, lift and drag coefficient; dimensional analysis; technique of dimensional analysis: Rayleigh's technique, Buckingham  $\pi$ -theorem.
8. **Steady and Unsteady Laminar Flow:** Exact solutions of steady and unsteady plane flows: Parallel flow through a straight channel and generalized Couette flows; plane Poiseuille flow; flow through a circular pipe-the Hagen-Poiseuille flow; flow between two parallel plates; flow over a suddenly accelerate flat plate; flow over an oscillating wall. General concepts and properties of boundary layer theory; Prandtl's boundary layer equations; similarity concepts and similarity solutions of the boundary layer equations.

#### Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

**CLO1.** Learn equations of continuity and Euler's equation of motion

**CLO2.** Gather knowledge about Bernoulli's equations and its application

**CLO3.** Know about circulation and vorticity

**CLO4.** Acquire knowledge about sources, sinks and doublets

**CLO5.** Learn the basic knowledge on fluid properties

**CLO6.** Know the Navier-Stokes equations of motion of a viscous fluid

**CLO7.** Study the dimensional analysis

**CLO8.** Derive the exact solutions of steady and unsteady plane flows

**CLO9.** Analyze Prandtl's boundary layer equations in many problems

#### Mapping of CLOs with PLOs:

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               | x         | x                              | x    |      | x    | x    |      |      |       |       | x     |
| CLO2        | x               | x         | x                              | x    |      | x    | x    |      |      |       |       | x     |
| CLO3        | x               | x         | x                              | x    |      |      | x    |      |      |       |       | x     |
| CLO4        | x               | x         | x                              | x    |      | x    | x    |      |      |       |       |       |
| CLO5        | x               | x         | x                              | x    |      | x    | x    |      |      |       |       |       |
| CLO6        | x               | x         |                                | x    |      | x    | x    |      |      |       |       |       |
| CLO7        | x               | x         | x                              | x    |      | x    | x    |      |      |       |       |       |
| CLO8        | x               | x         | x                              |      |      | x    | x    |      |      |       |       |       |
| CLO9        | x               | x         | x                              | x    |      | x    | x    |      |      |       |       |       |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                                                                                            | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | Preliminaries of hydrodynamics                                                                                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | Continuous Motion                                                                                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | Two-Dimensional Flow                                                                                             | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                          | Circle Theorem and Complex Dynamics                                                                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                          | Fundamentals of Fluid Dynamics                                                                                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                          | Navier-Stokes equations of motion of a viscous fluid                                                             | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                          | Dimensional Analysis                                                                                             | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8                          | Exact solutions of steady and unsteady plane flows                                                               | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO9                          | Prandtl's boundary layer equations; similarity concepts and similarity solutions of the boundary layer equations | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which answer any **Five (05)** questions and taking at least **Two (02)** questions from each group.

**References:**

1. L.M. Milne-Thomson, Theoretical Hydrodynamics, Dover Publication.
2. F.M. White, Fluid Mechanics, McGraw-Hill
3. H. Schlichting, Boundary Layer Theory, McGraw-Hill, New York.
4. F. Chorlton, A Text Book of Fluid dynamics, CBS Publication.

| MTH 411: Combinatorics      |                         |                       |                          |
|-----------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 411</b> | <b>Credit Hours:</b>    | <b>Year: Fourth</b>   | <b>Semester:</b>         |
| <b>Course Title:</b>        | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Combinatorics</b>        | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>      | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                             | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

Combinatorics is a field of mathematics concerned with counting and finite structures. It is the study of discrete structures, which are ubiquitous in our everyday lives. While Combinatorics has important practical applications (for example to networking, optimization, statistical physics, etc.), problems of a combinatorial nature also arise in many areas of pure mathematics such as algebra, probability, topology and geometry. The goal of this course is to introduce a variety of techniques and ideas that will help to solve a wide range of problems.

**Course Objectives:**

1. Become familiar with fundamental combinatorial structures that naturally appear in various other fields of mathematics and computer science
2. Learn counting techniques
3. Emphasis to apply counting methods to solve problems
4. Write coherent and logically sound arguments
5. Assimilate and use of novel and abstract ideas.

**Course Contents:**

1. **Strings, Sets and Binomial Coefficients:** Introduction to enumeration of strings of letters or numbers with restrictions, as well as permutations and combinations, Combinatorial proofs and the binomial theorem.
2. **Inclusion-Exclusion:** Basics of Inclusion-exclusion, Derangements, Mobius inversion, Stirling and Bell numbers, partitions, recursive formulae, Rook number, Rook polynomials, Erdos-KoRado theorem.
3. **Well-ordering, Recurrence, Induction and Generating Functions:** A variant of induction suitable for recurrences; existence theorem; Strong Induction, Pigeonhole Principle and Complexity. Nonhomogeneous and nonlinear recurrence equations.
4. **Graph and Counting Graphs:** Finite geometries of graphs and their automorphism groups, Colorings, Chromatic polynomials, Turan's theorem, Matching, Hall's Theorem, Exact and asymptotic enumerations for certain graphs of given size. Graph algorithms (Networks and the Max-flow min-cut theorem).
5. **Probability:** Basic concepts and their relation to enumeration. Discrete random variables, Ramsey number, Ramsey's theorem and some of its variants. Concentration inequalities. An introduction to information theory.
6. **Polya's Enumeration Theorem:** Coloring the vertices of a square, Burnside Lemma, Polya's theorem and its application.
7. **Combinatorics in Different Faces:** Markov chain, The Stable Matching theorem, Arithmetic Combinatorics, Lovasz Local Lemma. Combinatorial games.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**COL1.** Select and justify appropriate tools (induction, graphs, recurrences, complexity theory, generating functions, and probability) to analyze a counting problem.

**COL2.** Analyze a counting problem by proving an exact or approximate enumeration, or a method to compute one efficiently.

**COL3.** Describe solutions to iterated processes by relating recurrences to induction, generating functions, or combinatorial identities.

**COL4.** Understand, be able to prove and apply the fundamental results derived in the course, and solve unseen problems of similar kind; understand and be able to apply methods from elementary probability, analysis and linear algebra to a range of problems in discrete mathematics, including Ramsey theory.

**COL5.** Construct counting problems which show the usefulness or limitations of combinatorial tools.

**COL6.** Gain an appreciation of how methods from probability, analysis and algebra can be used to solve problems in discrete mathematics.

**CLO7.** Understanding problem of Markov chain

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                                                | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | <b>Strings, Sets and Binomial Coefficients</b>                       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | <b>Inclusion-Exclusion</b>                                           | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | <b>Well-ordering, Recurrence, Induction and Generating Functions</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                          | <b>Graph and Counting Graphs</b>                                     | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                          | <b>Probability</b>                                                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                          | <b>Polya's Enumeration Theorem</b>                                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                          | <b>Combinatorics in Different Faces</b>                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. M.T. Keller and W.T. Trotter, Applied Combinatorics,
2. Ralph P. Grimaldi, Discrete and Combinatorial Mathematics, Addison Wesley
3. Alan Tucker, Applied Combinatorics, Wiley & Sons
4. Richard A. Brualdi, Introductory Combinatorics, Pearson
5. B. Douglas, Introduction to Graph Theory, Prentice Hall

**MTH 412: Fuzzy Mathematics**

|                             |                         |                       |                          |
|-----------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 412</b> | <b>Credit Hours:</b>    | <b>Year: Fourth</b>   | <b>Semester:</b>         |
| <b>Course Title:</b>        | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Fuzzy Mathematics</b>    | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>      | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                             | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

Fuzzy Mathematics is based on fuzzy set theory. Fuzzy set theory is the study on fuzzy logic which is based on fuzzy sets, introduced by L. A. Zadeh in 1965, and symbolic logic. Fuzzy set theory is generalization of abstract set theory. Because of the generalization, it has a much wider scope of applicability than abstract set theory in solving various kinds of real physical world problems, particularly in the fields of pattern classification, information processing, control, system identification, artificial intelligence, and, more generally, decision processes involving uncertainty, impreciseness, vagueness, and doubtful data. The notation, terminology, and concept of Fuzzy Mathematics are helpful for students to obtain primary idea in studying and solving various kinds of real physical world problems.

**Course Objectives:**

1. To give the idea of fuzzy sets, operations on them, and the notion of fuzzy logic.
2. To understand the difference between classical set theory and fuzzy set theory.
3. To give the idea of relationship between classical set and fuzzy set via alpha-cut and strong alpha cut representation, the convexity of fuzzy sets, and Extension Principle for fuzzy sets.
4. To give the notion of fuzzy numbers, arithmetic operations on them, and Lattice of fuzzy Numbers.
5. To give the idea of linear fuzzy equations.
6. To give the concept of fuzzy relations and operations, similarity fuzzy relation, fuzzy morphism, and fuzzy relation equation.
7. To give the idea of the applications of fuzzy set theory.

**Course Contents:**

1. **Crisp Sets and Fuzzy Sets:** An overview of crisps sets; the notion of fuzzy sets; basic
2. **Concepts of Fuzzy Sets:** An overview of classical logic; fuzzy logic.
3. **Operations of Fuzzy Sets:** General discussion; fuzzy complement; fuzzy union; fuzzy intersection combinations of operations; general aggregation operations.

4. **Fuzzy Arithmetic:** fuzzy numbers, linguistic variables, arithmetic operations on intervals and fuzzy numbers, lattice of fuzzy numbers, fuzzy equations.
5. **Fuzzy Relations:** Crisp and fuzzy relations; binary relations on a set; equivalence and similarity relations; compatibility or tolerance relations; orderings; morphisms; fuzzy relational equations.
6. **Applications of Fuzzy Set Theory.**

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Gather knowledge about fuzzy logic, fuzzy set theory and understand the difference between classical set and fuzzy set.

**CLO2.** Achieve knowledge of conversion of fuzzy set to classical set and vice versa via alpha-cut and strong alpha-cut representation, and some additional properties of via alpha-cut and strong alpha cut.

**CLO3.** Gather knowledge about the necessary and sufficient condition of a fuzzy set to be a fuzzy number.

**CLO4.** Be able to do arithmetic operations of two fuzzy numbers and be also able to calculate their maximum and minimum.

**CLO5.** Achieve knowledge of the concept of the procedure to get a solution of fuzzy equations.

**CLO6.** Obtain the concept of binary fuzzy relation, domain, range, and inverse, composition of two binary fuzzy relations, some definitions, and theorems with proofs.

**CLO7.** Achieve the idea of applications of fuzzy set theory and learn the methodology of using fuzzy sets in a real-life problem.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              | x    |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           |                                | x    |      | x    |      |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                            | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|----------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | <b>Crisp Sets and Fuzzy Sets</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | <b>Operations of Fuzzy Sets</b>  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | <b>Fuzzy Arithmetic</b>          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

|      |                                         |                                                                                        |                                                            |
|------|-----------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO4 | <b>Fuzzy Relations</b>                  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5 | <b>Applications of Fuzzy Set Theory</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.  
**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. G. J. Klir & U. Clair, Fuzzy Set Theory: Foundations and Applications, Prentice Hall
2. G. J. Klir & Bo Yuan, Fuzzy Sets & Fuzzy Logic Theory and Applications, Pearson
3. R. Lowen, Fuzzy Set Theory: Basic Concepts, Techniques and Bibliography, Springer
4. H. J. Zimmermann, Fuzzy Sets Theory and Its Applications, Springer

| <b>MTH 413: Population Dynamics</b> |                         |                       |                          |
|-------------------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 413</b>         | <b>Credit Hours:</b>    | <b>Year: Fourth</b>   | <b>Semester:</b>         |
| <b>Course Title:</b>                | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Population Dynamics</b>          | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>              | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                                     | <b>Theory</b>           |                       | <b>2023-2026</b>         |

**Rationale:**

Mathematics is playing an important role in the physical and biological sciences. It has genuine uses in biology (as well as physical sciences) describing some models in population biology and the mathematics that is useful in analyzing them. Knowledge of dynamical properties is crucial in determining the existence and stability of associated solutions (equilibria) of the models. The goal of this course is to use mathematics as a tool for gaining a deeper understanding of biological systems and their dynamics.

**Course Objectives:**

Students will

1. have idea about different dynamical techniques
2. know how to develop simple models based on biological/physical phenomena
3. have basic understanding regarding biological systems
4. be able to analyze biological models using mathematics
5. have some basic ideas about the features of emerging and re-emerging disease

**Course Contents:**

1. **Basic Concepts:** Population dynamics; phase space, phase portrait; discrete and continuous systems; conjugacy; fixed points, periodic points, hyperbolic point and their stability.
2. **Dynamics of One Dimensional Maps:** One parameter family of maps; contraction mapping; stability of fixed points and periodic points; family of logistic maps; tent map; doubling map; linear maps; iterative map and quadratic family.

3. **Population Dynamics for Single Species:** Single species population models; Malthusian model; Logistic model; migration model; Smith model; time-varying environment model; time-delay model; harvesting model.
4. **Continuous Models for Interacting Population:** Two species population models; Lotka-Volterra model; competition model; cooperation model; war model.
5. **Discrete Population Models:** Simple discrete models; Malthusian discrete model; Logistic discrete model; discrete growth models for interacting populations; discrete delay models.
6. **Disease Models:** Simple epidemic models - SI model; SIS model; SIR model; infectious disease models (HIV/AIDS).
7. **Optimal Control:** Basic Optimal control problems and necessary conditions; existence and uniqueness of solution; principle of optimality.

#### **Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

- CLO1.** Explain the modeling concepts  
**CLO2.** Single species population modeling idea  
**CLO3.** Single species with harvesting and application  
**CLO4.** Multispecies population and interaction concepts  
**CLO5.** Competitive population dynamics and scenario  
**CLO6.** Discrete disease problems and their clarification for population  
**CLO7.** Communicable disease modeling and application  
**CLO8.** Infectious disease and their qualitative analysis  
**CLO9.** Optimal controlling strategy and its significance.

#### **Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              | x    | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           |                                | x    |      |      | x    |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      | x     |       |       |
| CLO6        | x               |           | x                              |      |      |      |      | x    |      |       |       | x     |
| CLO7        | x               |           |                                |      |      |      |      |      |      |       |       | x     |
| CLO8        | x               |           |                                | x    |      |      | x    |      |      | x     |       | x     |
| CLO9        | x               |           | x                              |      |      |      | x    |      |      |       |       | x     |

#### **Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course<br>Learning<br>Outcome<br>(CLO) | Topic                                 | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|----------------------------------------|---------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                                   | Basic Concepts of Population dynamics | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                                   | Dynamics of one dimensional maps      | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

|      |                                              |                                                                                        |                                                            |
|------|----------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO3 | Population Dynamics for Single Species       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4 | Continuous Models for Interacting Population | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5 | Discrete Population Models                   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6 | Multi-species population model.              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7 | Disease Models                               | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8 | HIV/AIDS, TB model                           | Lecture, recommended textbook, worksheets, printed solutions                           | Class test and final written examination, assignment, viva |
| CLO9 | Optimal Control                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. Steven H Strogatz, Nonlinear Dynamics and Chaos. CRC Press.
2. F Brauer, C Castillo-Chavez, Mathematical models in population biology and Epidemiology. Springer.
3. Suzanne Lenhart, John T Workman: Optimal Control Applied to Biological Models. Chapman & Hall/CRC, Taylor & Francis Group.
4. Leah Edelstein-Keshet, Mathematical Models in Biology. Siam.
5. J. D. Murray, Mathematical Biology, Springer.

| MTH 414: Scientific Computing and Simulations                |                                                 |                       |                                       |
|--------------------------------------------------------------|-------------------------------------------------|-----------------------|---------------------------------------|
| <b>Course Code: MTH 414</b>                                  | <b>Credit Hours:</b>                            | <b>Year: Fourth</b>   | <b>Semester:</b>                      |
| <b>Course Title:</b><br>Scientific Computing and Simulations | <b>3.00 Hrs/Week</b><br><b>Total Marks: 100</b> |                       |                                       |
| <b>Course Teacher:</b>                                       | <b>Course Type:</b><br>Theory                   | <b>Pre-requisite:</b> | <b>Academic Session:</b><br>2023-2026 |

**Rationale:**

Scientific computing and simulations play a vital role in various areas of science ranging from biology to modeling of complex physical systems. Various algorithms and mathematical methods are used in computing and simulations. Scientific computing is now considered as another distinct mode of science and it complements and builds relation between theory and experimentations. This course will help to formulate a model of a practical phenomenon, then to develop an algorithm after discretizing the model and finally, the execution of the algorithm as a computer programming.

**Course Objectives:**

1. A rigorous description of the concepts of symbolic algorithms.
2. Contemporary knowledge on some methods and techniques.
3. The knowledge of implementation of methods by using some software packages and toolkits.
4. Introductory ideas about deterministic and stochastic simulations.

**Course Contents:**

1. Introduction to scientific computing
2. Introduction to symbolic mathematics systems. Effective use of symbolic mathematics systems and their limitations.
3. Program design; writing well-structured programs; debugging techniques.
4. Data analysis, plotting and smoothing;
5. Key mathematical algorithms such as the Euclidean algorithm and the fast Fourier transform.
6. **Modular algorithms and interpolation:** Introduction to modular algorithms, their efficient implementation for fast symbolic/numeric computations. Curve Fitting and Interpolation.
7. Modelling of Biological Systems, Artificial Intelligence, Statistical Computing.
8. Number theoretic algorithms in coding and cryptography.
9. Fast algorithms for multiplication of numbers and polynomials, for manipulation of series, fast matrix manipulation, fast factorization of polynomials, Integer and polynomial arithmetic, Solution of systems of polynomial. Applications of Groebner.
10. Modern algorithms for sorting, searching and retrieving information with applications to genomic research and text processing.
11. **Introduction to parallel computing:** Threaded programming versus message passing, Parallel Processing and Grid Computing
12. **Stochastic simulations:** Monte Carlo method, Continuum simulations: Schrodinger equation in quantum mechanics.

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Master the main methods of non-numerical analysis of functions and processes

**CLO2.** Use the modern algorithms for searching information in targeted areas and the bases of algorithm construction and analysis

**CLO3.** Apply these methods to academic and simple practical instances

**CLO4.** Develop the abilities to design and conduct advanced numeric and symbolic experiments appropriate for an applied mathematical model, analyze and interpret their results.

**CLO5.** Apply various simulations in to solve practical problems in diverse fields.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |

|      |   |  |   |  |  |   |  |  |  |  |  |   |  |
|------|---|--|---|--|--|---|--|--|--|--|--|---|--|
| CLO5 | x |  | x |  |  | x |  |  |  |  |  | x |  |
|------|---|--|---|--|--|---|--|--|--|--|--|---|--|

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                                                                                                                                   | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | Introduction to symbolic mathematics systems                                                                                                            | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | Exact versus approximate computation                                                                                                                    | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | Key mathematical algorithms such as the Euclidean algorithm and the fast Fourier transform                                                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                          | Integer and polynomial arithmetic                                                                                                                       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                          | Introduction to modular algorithms, their efficient implementation for fast symbolic/numeric computations.                                              | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                          | Number theoretic algorithms in coding and cryptography                                                                                                  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO7                          | Fast algorithms for multiplication of numbers and polynomials, for manipulation of series, fast matrix manipulation, fast factorization of polynomials. | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO8                          | Algorithmically solvable and unsolvable problems                                                                                                        | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO9                          | Modern algorithms for sorting, searching and retrieving information with applications to genomic research and text processing.                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO10                         | Quantifier elimination and applications to stability analysis and control theory                                                                        | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**.

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. J. von zurGathen and J. Gerhard. Modern Computer Algebra. Cambridge University Press, 3rd ed., 2013
2. J.A. Storer. An Introduction to Data Structures and Algorithms. Springer, 2002
3. D.Sankoff, J.Kruskal. Time Warps, String Edits, and Macromolecules. The Theory and Practice of Sequence Comparison (CSLI Pub., 1999)

| MTH 415: Introduction to Mathematical Finance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                  |                       |                                       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|-----------------------|---------------------------------------|
| <b>Course Code: MTH 415</b><br><b>Course Title:</b><br>Introduction to Mathematical Finance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>Credit Hours:</b><br>3.00 Hrs/Week<br><b>Total Marks: 100</b> | <b>Year: Fourth</b>   | <b>Semester:</b>                      |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>Course Type:</b><br>Theory                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br>2023-2026 |
| <p><b>Rationale:</b></p> <p>Continuation of 3<sup>rd</sup> year module ‘Stochastic Calculus’ to the modern Mathematical Finance area. The domain of stochastic processes, mainly Brownian motion, in the application area of mathematical finance has been introduced with rigorous structural studies. Celebrated Black and Scholes model has been introduced, derived and intuitively explained which paves the path to study more advanced jump processes and ARCH/GARCH processes in mathematical finance area in MS.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                  |                       |                                       |
| <p><b>Course Objectives:</b></p> <p>To get the stochastic mathematics concepts providing grounds to study the stock markets, bond markets and financial risk management used in banks and insurance companies; to engage in research and further studies in the horizon of Mathematical Finance, Actuarial Science and Financial Risk Management. Numerical simulation of studies of SDE’s used in these areas are also in the objectives of this module.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                  |                       |                                       |
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li><b>1. Geometric Brownian Motion and Black-Scholes Model:</b> Random Walk to BM; construction of BM; BM in stock price dynamics; covariance and correlation of BMN; slope, non-differentiability and measurement of variability of BM paths, examples of Models.</li> <li><b>2. Martingale and Black-Scholes PDE:</b> Filtration, sigma-algebra, conditional expectation and martingale; properties of conditional expectation and martingale; examples of martingale analysis; revisiting BM as martingale.</li> <li><b>3. Stochastic Integral and Solutions of Black-Scholes:</b> Stochastic for non-random step functions and for non-anticipating general random integrands; properties of Ito Stochastic integrals; Stochastic differential equations and Ito integrals: functions of BM and frequently used Ito integrals for BM.</li> <li><b>4. SDE and Calibration of Black-Scholes Model:</b> Structure of SDE; SDE for arithmetic BM; SDE for geometric BM; Ornstein-Uhlenbeck SDE; mean reversion SDE; square root SDE; Diffusion SDE. Introductory solutions of SDE.</li> <li><b>5. Option Valuation:</b> PDE method; Martingale method in one period binomial framework; martingale method in continuous time framework; valuation of European options like digital call, Asset-or-noting call, standard European call.</li> </ol> |                                                                  |                       |                                       |
| <p><b>Course Learning Outcomes (CLOs):</b></p> <p>After the successful completion of the course, students will be able to:</p> <p><b>CLO1.</b> Understanding of Random Walk to BM; construction of BM; BM in stock price dynamics; covariance and correlation of BMN</p> <p><b>CLO2.</b> Learn properties of conditional expectation and martingale;</p> <p><b>CLO3.</b> Use of Stochastic differential equations and Ito integrals for BM</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                  |                       |                                       |

|                                                                                                                                                                                                                                |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|-----------|--------------------------|----------------------------------------------------------------------------------------|------|------|------|------------------------------------------------------------|------|-------|-------|-------|
| <b>CLO4.</b> Use of SDE for arithmetic BM; geometric BM                                                                                                                                                                        |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
| <b>CLO5.</b> Understanding the solution of SDE                                                                                                                                                                                 |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
| <b>CLO6.</b> Understanding of Martingale method in one period binomial framework                                                                                                                                               |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
| <b>CLO7.</b> Use of martingale method in continuous time framework                                                                                                                                                             |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
| <b>CLO8.</b> Valuation of European options like digital call, Asset-or-noting call, standard European call                                                                                                                     |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
| <b>Mapping of CLOs with PLOs:</b>                                                                                                                                                                                              |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
| CLO/ PLO                                                                                                                                                                                                                       | PLO1 (Funda)                             | PLO2(Lab) | PLO3 (Critical Thinking) | PLO4                                                                                   | PLO5 | PLO6 | PLO7 | PLO8                                                       | PLO9 | PLO10 | PLO11 | PLO12 |
| CLO1                                                                                                                                                                                                                           | x                                        |           | x                        |                                                                                        | x    | x    | x    | x                                                          | x    | x     | x     | x     |
| CLO2                                                                                                                                                                                                                           | x                                        |           | x                        |                                                                                        |      |      |      |                                                            | x    |       |       | x     |
| CLO3                                                                                                                                                                                                                           | x                                        |           | x                        |                                                                                        |      |      |      |                                                            |      |       |       | x     |
| CLO4                                                                                                                                                                                                                           | x                                        |           | x                        |                                                                                        |      |      |      |                                                            |      |       |       | x     |
| CLO5                                                                                                                                                                                                                           | x                                        |           | x                        |                                                                                        |      | x    |      |                                                            |      |       |       | x     |
| CLO6                                                                                                                                                                                                                           | x                                        |           | x                        |                                                                                        |      |      |      |                                                            |      |       |       | x     |
| CLO7                                                                                                                                                                                                                           | x                                        |           |                          |                                                                                        |      |      |      |                                                            |      |       |       | x     |
| CLO8                                                                                                                                                                                                                           | x                                        |           |                          |                                                                                        |      |      | x    |                                                            |      |       |       | x     |
| <b>Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning &amp; Assessment Strategy:</b>                                                                                                                           |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
| Course Learning Outcome (CLO)                                                                                                                                                                                                  | Topic                                    |           |                          | Teaching-Learning Strategies                                                           |      |      |      | Assessment Strategies                                      |      |       |       |       |
| CLO1                                                                                                                                                                                                                           | Brownian Motion (BM)                     |           |                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      | Class test and final written examination, assignment, viva |      |       |       |       |
| CLO2                                                                                                                                                                                                                           | Martingale:                              |           |                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      | Class test and final written examination, assignment, viva |      |       |       |       |
| CLO3                                                                                                                                                                                                                           | Ito Stochastic Integral and Ito Calculus |           |                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      | Class test and final written examination, assignment, viva |      |       |       |       |
| CLO4                                                                                                                                                                                                                           | Stochastic Differential Equations (SDE)  |           |                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      | Class test and final written examination, assignment, viva |      |       |       |       |
| CLO5                                                                                                                                                                                                                           | Option Valuation                         |           |                          | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector |      |      |      | Class test and final written examination, assignment, viva |      |       |       |       |
| <b>Evaluation:</b> In-course Assessment: <b>30 Marks</b> . Final Examination (Theory, 3 Hours): <b>70 Marks</b> .<br><b>Eight (08)</b> questions of equal value will be set, of which any <b>Five (05)</b> are to be answered. |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
| <b>References:</b>                                                                                                                                                                                                             |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
| 1. Ubbo F. Wiersema, Brownian motion Calculus, John Wiley and Sons                                                                                                                                                             |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |
| 2. Steven E shreve, lecture notes: Stochastic Calculus for Finance-II.                                                                                                                                                         |                                          |           |                          |                                                                                        |      |      |      |                                                            |      |       |       |       |

| MTH 416: Stochastic Optimization                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                         |                       |                                              |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------|----------------------------------------------|
| <b>Course Code: MTH 416</b><br><b>Course Title:</b><br><b>Stochastic Optimization</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>Credit Hours:</b><br><b>3.00 Hrs/Week</b><br><b>Total Marks: 100</b> | <b>Year: Fourth</b>   | <b>Semester:</b>                             |
| <b>Course Teacher:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Course Type:</b><br><b>Theory</b>                                    | <b>Pre-requisite:</b> | <b>Academic Session:</b><br><b>2023-2026</b> |
| <p><b>Rationale:</b></p> <p>The aim of stochastic programming (SP) is precisely to find an optimal decision in problems involving uncertain data. In this terminology, stochastic is opposed to deterministic and means that some data are random, whereas programming refers to the fact that various parts of the problem can be modeled as linear or nonlinear mathematical programs. The field, also known as optimization under uncertainty, is developing rapidly with contributions from many disciplines such as operations research, economics, mathematics, probability, and statistics.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                         |                       |                                              |
| <p><b>Course Objectives:</b></p> <p>The objective of this course is to provide a wide overview of stochastic programming. Introduction to Stochastic Programming is intended as a first course for beginning graduate students or advanced undergraduate students in such fields as operations research, industrial engineering, business administration and mathematics. This course provides worked examples of modeling a stochastic program. It introduces the basic concepts, without using any new or specific techniques. It describes how a stochastic model is formally built. It also stresses the fact that different models can be built, depending on the type of uncertainty and the time when decisions must be taken.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                         |                       |                                              |
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li><b>1. Introduction:</b> Introduction to Stochastic Programming, basics of SP, formal approaches to stochastic programming, discussion of different problem classes and their characteristics, probability and random variables etc.</li> <li><b>2. Deterministic VS Stochastic Linear Program:</b> Linear Programming (LP) problems, LPs involving many variables when the outcome of the decisions can be predicted with uncertainty, uncertainty about the demand, uncertainty about the input prices, uncertainty about the technical coefficient matrix. LP equivalent of a SP.</li> <li><b>3. Two-Stage Recourse Problem:</b> Scenarios generation, formulation of scenario based SP, Formulation of 2-stage recourse problem, the solution in the 1st-stage, the solution in the second stage and application in real life. Fixed distribution pattern with fixed demand, fixed distribution pattern with uncertain demand, Variable distribution pattern with uncertain demand.</li> <li><b>4. Multi-Stage Recourse Problem:</b> Formulation of scenario based SP, Formulation of multi-stage recourse problem, solution in different methods and application in real life. Fixed distribution pattern with fixed demand, fixed distribution pattern with uncertain demand, Variable distribution pattern with uncertain demand.</li> <li><b>5. Chance Constrained SP:</b> Formulation of chance constrained SP, solution in different methods and application in real life.</li> <li><b>6. Stochastic Integer Program:</b> Formulation of stochastic integer program (IP), recourse problems, simple integer recourse, probabilistic constraints, and solution in different methods and application in real life.</li> </ol> |                                                                         |                       |                                              |

**Course Learning Outcomes (CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Understanding Stochastic Programming

**CLO2.** Apply Deterministic and Stochastic Linear Program

**CLO3.** Understanding Two-Stage Recourse Problem

**CLO4.** Apply Multi-Stage Recourse Problem

**CLO5.** Formulation of chance constrained SP, solution in different methods and application in real life.

**CLO6.** Formulation of stochastic integer program (IP), recourse problems

**CLO7.** ability to find information through tools like the world-wide web to solve problems;

**CLO8.** ability to use computers to solve stochastic problems;

**CLO9.** competency in mathematical presentation, and written and verbal skills.

**Mapping of CLOs with PLOs:**

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | x               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | x               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | x               |           |                                |      |      |      |      |      |      |       |       | x     |
| CLO8        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |
| CLO9        | x               |           |                                |      |      |      | x    |      |      |       |       | x     |

**Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:**

| Course Learning Outcome (CLO) | Topic                                              | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|----------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | <b>Introduction</b>                                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | <b>Deterministic VS Stochastic Linear Program:</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | <b>Two-Stage Recourse Problem</b>                  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO4                          | <b>Multi-Stage Recourse Problem</b>                | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO5                          | <b>Chance Constrained SP</b>                       | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO6                          | <b>Stochastic Integer Program</b>                  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** In-course Assessment: **30 Marks.** Final Examination (Theory, 3 Hours): **70 Marks.**

**Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**References:**

1. John R. Birge and Francois Louveaux, Introduction to Stochastic Programming, Springer Series in Operations Research and Financial Engineering,
2. Peter Kall and Stein Wallace, Stochastic Programming, JOHN WILEY & SONS, New Yourk, USA.
3. Urmila Diwekar, Introduction to Applied Optimization, Springer, Vishwamitra Research Institute, Clarendon Hills, IL, USA.
4. Lecture on Stochastic Programming: Modelling and Theory, SIAM, Alexander Shapiro, Darinka Dentcheva and Andrzej Ruszczyński. Philadelphia.

**MTH 420: Special Topics**

**Credit: 3**

Any mathematical topic not covered in other courses may be offered under this title. The course-teacher will prepare an outline of the course and obtain the approval of the departmental academic committee.

**Evaluation:** In-course Assessment: **30 Marks**. Final Examination (Theory, 3 Hours): **70 Marks**. **Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

**MTH 450: Math Lab IV (MATLAB)**

|                             |                         |                       |                          |
|-----------------------------|-------------------------|-----------------------|--------------------------|
| <b>Course Code: MTH 450</b> | <b>Credit Hours:</b>    | <b>Year: Second</b>   | <b>Semester:</b>         |
| <b>Course Title:</b>        | <b>3.00 Hrs/Week</b>    |                       |                          |
| <b>Math Lab IV (MATLAB)</b> | <b>Total Marks: 100</b> |                       |                          |
| <b>Course Teacher:</b>      | <b>Course Type:</b>     | <b>Pre-requisite:</b> | <b>Academic Session:</b> |
|                             | <b>Lab</b>              |                       | <b>2023-2026</b>         |

**Rationale:**

MATLAB (stands for Matrix Laboratory) is the advanced fourth-generation programming language that is widely employed to create an easy-to-perform environment for the mathematical notations. Its best applications include Data Analysis, Mathematics and Computation, Algorithm Developments, Visualization, etc. The MATLAB teach you how to use this tool for symbolic computation and developing algorithms. Graduates, Post Graduates, Working Professionals, Researchers and Developers can enroll in these courses to develop expertise in the basic functionalities of MATLAB software.

**Course Objectives:**

1. Use programming operations to calculate solutions
2. Determine better and more accurate solutions

| <ol style="list-style-type: none"> <li>3. Perform and evaluate algebraic and trigonometric operations using built-in functions</li> <li>4. Assign and manage variables</li> <li>5. Manipulate vectors and matrices, use matrix indexing, and determine matrix dimensions</li> <li>6. Generate linearly spaced vectors</li> <li>7. Create and execute a script</li> <li>8. Create and evaluate x-y plots and subplots suitable for technical presentation</li> <li>9. Create, test, and execute user-defined functions and sub-functions Create function input validation</li> <li>10. Distinguish between the different MATLAB 'data types'</li> <li>11. Create and manipulate Structures and Arrays</li> <li>12. Perform and evaluate relational and logical operations</li> <li>13. Load, analyze, and manipulate images</li> <li>14. Obtain and utilize user input</li> <li>15. Manage and format text output</li> <li>16. Import and export numeric data using other filetypes (e.g. .csv, .xls, and .txt)</li> <li>17. Perform polynomial curve-fitting, general curve fitting, and interpolation</li> <li>18. Perform numeric and symbolic differentiation and integration</li> <li>19. Solve non-linear systems of equations</li> <li>20. Solve numeric ODE's</li> <li>21. Build a block diagram in Simulink to perform an operation</li> <li>22. Perform numerical optimization</li> <li>23. Analyze Signals</li> </ol> |                 |           |                                |      |      |      |      |      |      |       |       |       |             |                 |           |                                |      |      |      |      |      |      |       |       |       |      |   |  |   |  |   |   |   |   |   |   |   |   |      |   |  |   |  |  |  |  |  |   |  |  |   |      |   |  |   |  |  |  |  |  |  |  |  |   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|------|---|--|---|--|---|---|---|---|---|---|---|---|------|---|--|---|--|--|--|--|--|---|--|--|---|------|---|--|---|--|--|--|--|--|--|--|--|---|
| <p><b>Course Contents:</b></p> <ol style="list-style-type: none"> <li>1. Problems Solving: Problems in the courses of Fourth Year BS Honours will be solved using Computer Algebra System (CAS) MATLAB.</li> <li>2. Lab Assessment: Take Class Test.</li> <li>3. Lab Assignments: Course instructors will provide a list of Lab assignments.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                 |           |                                |      |      |      |      |      |      |       |       |       |             |                 |           |                                |      |      |      |      |      |      |       |       |       |      |   |  |   |  |   |   |   |   |   |   |   |   |      |   |  |   |  |  |  |  |  |   |  |  |   |      |   |  |   |  |  |  |  |  |  |  |  |   |
| <p><b>Course Learning Outcomes (CLOs):</b></p> <p>After the successful completion of the course, students will be able to:</p> <p><b>CLO1.</b> Understanding MATHEMATICA/ MATLAB/ FORTRAN/ C/ Mapple.</p> <p><b>CLO2.</b> Apply any of the programming language in higher study.</p> <p><b>CLO3.</b> Solve real life problem using the programming language.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                 |           |                                |      |      |      |      |      |      |       |       |       |             |                 |           |                                |      |      |      |      |      |      |       |       |       |      |   |  |   |  |   |   |   |   |   |   |   |   |      |   |  |   |  |  |  |  |  |   |  |  |   |      |   |  |   |  |  |  |  |  |  |  |  |   |
| <p><b>Mapping of CLOs with PLOs:</b></p> <table border="1"> <thead> <tr> <th>CLO/<br/>PLO</th><th>PLO1<br/>(Funda)</th><th>PLO2(Lab)</th><th>PLO3<br/>(Critical<br/>Thinking)</th><th>PLO4</th><th>PLO5</th><th>PLO6</th><th>PLO7</th><th>PLO8</th><th>PLO9</th><th>PLO10</th><th>PLO11</th><th>PLO12</th></tr> </thead> <tbody> <tr> <td>CLO1</td><td>x</td><td></td><td>x</td><td></td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td></tr> <tr> <td>CLO2</td><td>x</td><td></td><td>x</td><td></td><td></td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td></tr> <tr> <td>CLO3</td><td>x</td><td></td><td>x</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>x</td></tr> </tbody> </table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                 |           |                                |      |      |      |      |      |      |       |       |       | CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 | CLO1 | x |  | x |  | x | x | x | x | x | x | x | x | CLO2 | x |  | x |  |  |  |  |  | x |  |  | x | CLO3 | x |  | x |  |  |  |  |  |  |  |  | x |
| CLO/<br>PLO                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |             |                 |           |                                |      |      |      |      |      |      |       |       |       |      |   |  |   |  |   |   |   |   |   |   |   |   |      |   |  |   |  |  |  |  |  |   |  |  |   |      |   |  |   |  |  |  |  |  |  |  |  |   |
| CLO1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |             |                 |           |                                |      |      |      |      |      |      |       |       |       |      |   |  |   |  |   |   |   |   |   |   |   |   |      |   |  |   |  |  |  |  |  |   |  |  |   |      |   |  |   |  |  |  |  |  |  |  |  |   |
| CLO2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | x               |           | x                              |      |      |      |      |      | x    |       |       | x     |             |                 |           |                                |      |      |      |      |      |      |       |       |       |      |   |  |   |  |   |   |   |   |   |   |   |   |      |   |  |   |  |  |  |  |  |   |  |  |   |      |   |  |   |  |  |  |  |  |  |  |  |   |
| CLO3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | x               |           | x                              |      |      |      |      |      |      |       |       | x     |             |                 |           |                                |      |      |      |      |      |      |       |       |       |      |   |  |   |  |   |   |   |   |   |   |   |   |      |   |  |   |  |  |  |  |  |   |  |  |   |      |   |  |   |  |  |  |  |  |  |  |  |   |
| <p><b>Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning &amp; Assessment Strategy:</b></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                 |           |                                |      |      |      |      |      |      |       |       |       |             |                 |           |                                |      |      |      |      |      |      |       |       |       |      |   |  |   |  |   |   |   |   |   |   |   |   |      |   |  |   |  |  |  |  |  |   |  |  |   |      |   |  |   |  |  |  |  |  |  |  |  |   |

| Course Learning Outcome (CLO) | Topic                   | Teaching-Learning Strategies                                                           | Assessment Strategies                                      |
|-------------------------------|-------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------|
| CLO1                          | <b>Problems Solving</b> | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO2                          | <b>Lab Assessment</b>   | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |
| CLO3                          | <b>Lab Assignments</b>  | Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector | Class test and final written examination, assignment, viva |

**Evaluation:** Internal Assessment: **40 Marks**, Final Examination (Lab 3 Hours): **60 Marks**.

**Four (04)** questions of equal value will be set, of which **All Questions** are to be answered.

**References:**

7. MATLAB for Engineers, 6th edition, Holly Moore, Salt Lake Community College, Pearson Education Inc, 2022
8. Introduction to Scientific Computing by Charles F. Van Loan
9. Numerical Computing with Matlab" by Cleve Moler
10. MATLAB Handbook with Applications to Mathematics, Science, Engineering, and Finance by Jose Miguel David Baez-Lopez, David Alfredo Baez Villegas, Copyright 2019
11. Mathematical Modeling and Simulation with MATLAB, Sheldon Lee, La Crosse, WI Megan Buzby, Juneau, AK, Copyright Year: 2021
12. Advanced Engineering Mathematics with MATLAB, 5th edition, Dean G. Duffy, USNA, CRC Press, Inc., 2021

**MTH 490: Honours Project**

**Credit: 3**

Each student is required to work on a project and present a project report for evaluation. Such projects should be extensions or applications of materials included in different honours courses and may involve field work and use of technology. There may be group projects as well as individual projects.

**Evaluation:** Project implementation and evaluation rules are given in the appendix.

**MTH 499: Viva Voce**

**Credits: 2**

**Viva Voce on courses taught in the Fourth Year.**

**N.B. In the grading system the evaluation of any course (irrespective of its credit hours) should be carried out of 100 marks. In each theoretical course 30% will be reserved for internal assessment; in each Lab course 40% will be reserved for internal assessment.**

## **Appendix (Implementation and Evaluation of MTH 490: Honours Project)**

### **Implementation**

The Academic Committee shall appoint a Project Implementation and Coordination Committee (PICC) well before the session begins. The PICC shall consist of a project Coordinator (PC) and such other members as the Academic Committee considers appropriate.

The PC shall invite projects from the teachers before the class start. Each teacher should submit three project proposals should include a short description of the project. Such projects should be extension or applications of materials included in different honors courses, and may involve fieldwork and use of technology.

There may group projects as well as individual projects. For group projects, students will sign up with the PICC in groups of three. These may not be changed later on without approval of the PICC.

The PICC shall assign each group a project. The members of each group shall work independently on the assigned project under the supervision of the concerned teacher.

The PICC shall monitor with the supervisors the progress of different projects and arrange weekly discussions on projects and materials.

### **Completion**

The project must be completed before the termination of the classes. Each student is required to prepare a separate report on the project. Each report should be of around 40 pages typed on one side of A4 size white paper preferably using word processors. Graphs and figures should be clearly drawn preferably using computers. Reports of different students working on the same group project should differ in some details and illustrations.

The Academic Committee will fix a date for the submission of the project reports to the PICC. Each student must submit three typed copies of her/his project report to the PICC on or before the date fixed for such submission.

The PICC, on receiving the reports will arrange the presentation of reports by individual students before the PICC, this presentation should take place soon after the completion of the written examination.

Any student who fails to submit the report on the due date or to present the thesis on the fixed date will not get any credit for this course.

### **Course Learning Outcomes(CLOs):**

After the successful completion of the course, students will be able to:

**CLO1.** Learn how to write a research paper.

**CLO2.** Learn how to cite an article?

**CLO3.** Learn how to present research work?

**CLO4.** Learn how work in a group

**CLO5.** Learn how to lead a group

**CLO6.** Able to collection data for research

**CLO7.** Check parallelism

## Mapping of CLOs with PLOs

| CLO/<br>PLO | PLO1<br>(Funda) | PLO2(Lab) | PLO3<br>(Critical<br>Thinking) | PLO4 | PLO5 | PLO6 | PLO7 | PLO8 | PLO9 | PLO10 | PLO11 | PLO12 |
|-------------|-----------------|-----------|--------------------------------|------|------|------|------|------|------|-------|-------|-------|
| CLO1        | x               |           | x                              |      | x    | x    | x    | x    | x    | x     | x     | x     |
| CLO2        | X               |           | x                              |      |      |      |      |      | x    |       |       | x     |
| CLO3        | X               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO4        | X               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO5        | X               |           | x                              |      |      | x    |      |      |      |       |       | x     |
| CLO6        | X               |           | x                              |      |      |      |      |      |      |       |       | x     |
| CLO7        | X               |           |                                |      |      |      |      |      |      |       |       | x     |

**Evaluation:** The distribution of marks for each project shall be as follows:

**Project Report 50 marks.**

**Project Presentation 50 marks.**

Each project report shall be examined by two examiners, one of whom shall be the project supervisor and the other appointed from amongst the teachers of the department on the recommendation of the PICC. In case the marks of the two examiners of a project report differ by more than 20% a third examiner for that report shall be appointed from amongst the teachers of the department on the recommendation of the PICC. In such cases the final marks shall be determined according to the usual procedure.

Each student is required to present her/his work on the project before the PICC who will evaluate the presentation.

The Academic Committee may prepare additional guidelines for evaluation of the projects.

All marks on the projects shall be submitted to the Examination Committee for tabulation with copies to the Controller of Examinations. The project reports shall be returned to the PICC for preservation.