For Four-Year BS Honours Program
Affiliated Colleges
Department of Mathematics
University of Dhaka

Effective for 2022-2023 and 2023-2024

Total Credits: 133

List of Departmental and Non-Departmental Courses for First Year (32 Credits) Effective for 2022-2023 onwards

Course No.	Course Name	Credits
MAT 101	Fundamentals of Mathematics	3 credits
MAT 102	Differential Calculus I	3 credits
MAT 103	Analytic Geometry	3 credits
MAT 104	Linear Algebra I	3 credits
MAT 105	Integral Calculus I	3 credits
211501	History of Emergence of Independent Bangladesh	4 credits
MAT 150	Math Lab I (MATHEMATICA)	3 credits
MAT 199	Viva Voce	2 credits
	Total Major Credits	**24**
	Non-Departmental Courses (8 credits). **Choose any two Subjects from the following list**	
	Physics 4 Credits Statistics 4 Credits Economics 4 Credits	
	Total Credits from Non-Departmental Courses	**8**
	Total Credits	**32**

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

List of Departmental and Non-Departmental Courses for Second Year (34 Credits) Effective for 2023-2024 onwards

Course No.	Course Name	Credits
MAT 201	Real Analysis I	3 credits
MAT 202	Differential Calculus II	3 credits
MAT 203	Ordinary Differential Equations I	3 credits
MAT 204	Linear Algebra II	3 credits
MAT 205	Integral Calculus II	3 credits
MAT 206	Numerical Analysis I	3 credits
MAT 207	Programming Fundamentals	3 credits
MAT 250	Math Lab II (MATLAB)	3 credits
MAT 299	Viva Voce	2 credits
	Total Major Credits	**26**
Non-Departmental Courses (8 credits). Choose any two Subjects from the following list		
	Physics 4 Credits Statistics 4 Credits Economics 4 Credits	
	Total Credits from Non-Departmental Courses	**8**
	Total Credits	**34**

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

List of Courses for Third Year
(32 credits)
Effective for 2024-2025 onwards

Course No.	Course Name	Credits
MAT 301	Real Analysis II	3 credits
MAT 302	Complex Analysis	3 credits
MAT 303	Ordinary Differential Equations II	3 credits
MAT 304	Abstract Algebra I : Theory of Groups	3 credits
MAT 305	Fundamentals of Topology	3 credits
MAT 306	Numerical Analysis II	3 credits
MAT 307	Mathematical Methods	3 credits
MAT 308	Optimizations	3 credits
MAT 309	Discrete Mathematics	3 credits
MAT 350	Math Lab III (FORTRAN)	3 credits
MAT 399	Viva Voce	2 credits
	Total Credits	**32**

List of Courses for Fourth Year

(35 credits)
Effective for 2025-2026 onwards

Course No.	Course Name	Credits
MAT 401	Introduction to Functional Analysis	Credit 3
MAT 402	Partial Differential Equations	Credit 3
MAT 403	Differential Geometry and Tensor Calculus	Credit 3
MAT 404	Abstract Algebra II : Theory of Rings and Modules	Credit 3
MAT 405	Mechanics	Credit 3
MAT 406	Hydrodynamics	Credit 3
MAT 407	Introduction to Number Theory	Credits 3
Take any three from the following courses (**MAT 408 - MAT 412**)		
MAT 408	Fuzzy Mathematics	Credit 3
MAT 409	Population Dynamics	Credit 3
MAT 410	Lattice Theory	Credit 3
MTH 411	Difference Equations	Credit 3
MAT 412	Introduction to Actuarial Mathematics	Credit 3
MAT 450	Math Lab IV	Credit 3
MAT 499	Viva-voce	Credit 2
	Total Credits	**35**

Total Credits: 133

List of Non-Departmental Courses for 1st Year BS (Honours)

Mathematics Courses for Honours Students of the Departments other than Mathematics

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

First Year Minor

Course NO.	Course Names	Credits
MAM 101	Fundamentals of Mathematics	2 credits
MAM 102	Calculus I	2 credits
MAM 103	Analytic and Vector Geometry	2 credits
MAM 104	Linear Algebra	2 credits

List of Non-Departmental Courses for 2nd Year BS (Honours)

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

Course NO.	Course Names	Credits
MAM 202	Calculus II	2 credits
MAM 203	Ordinary Differential Equations	2 credits
MAM 204	Numerical Analysis	2 credits
MAM 205	Mathematical Methods	2 credits

List of Departmental and Non-Departmental Courses for First Year (32 Credits) Effective for 2022-2023 onwards

Course No.	Course Name	Credits
MAT101	Fundamentals of Mathematics	3 credits
MAT102	Differential Calculus I	3 credits
MAT103	Analytic Geometry	3 credits
MAT104	Linear Algebra I	3 credits
MAT105	Integral Calculus I	3 credits
211501	History of Emergence of Independent Bangladesh	4 credits
MAT150	Math Lab I (MATHEMATICA)	3 credits
MAT199	Viva Voce	2 credits
	Total Major Credits	**24**
	Non-Departmental Courses (8 credits). **Choose any two Subjects from the following list**	
	Physics 6 Credits Statistics 6 Credits Economics 6 Credits	
	Total Credits from Non-Departmental Courses	**8**
	Total Credits	**32**

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

MAT101: Fundamentals of Mathematics

Course Code: MAT101 **Course Title: Fundamentals of Mathematics**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

Course Objectives:

1. To give knowledge on some basic mathematical concepts.
2. To provide brief idea about the use of mathematical logic, methods of proofs, set theory, real and complex number system and inequality.
3. To give knowledge about the relations, functions in considerable detail.
4. To provide details knowledge of polynomial and polynomial equations, algebraic and geometric series and vectors.

Course Contents:

1. **Elements of Logic:** 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.
2. **Set Theory:** Sets and subsets; Set operations; Family of Sets; Cardinality of sets; De Morgan’s laws; Applications of Set Theory.
3. **Relations and Functions:** Cartesian product of sets; Relations; Order relation; Equivalence relations; Functions; Images and inverse images of sets.
4. **Real Number System:** Field and order properties; Natural numbers, integers and rational numbers; Absolute value; Basic inequalities including inequalities involving means, powers; Inequalities of Weierstrass, Cauchy, Chebyshev.
5. **Complex number system:** Field of complex numbers; Geometrical representations; Polar form; De Moivre’s theorem and its applications.
6. **Summation of finite series:** Arithmetic and geometric series; Method of difference; Successive differences; Summation of trigonometric series.
7. **Theory of equations:** 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).

8. **Algebra of vectors**: Scalar and vector products; Coplanar vectors; Scalar triple product; Vector triple product. Applications.

Course Learning Outcomes:

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

- Explain the foundations of mathematics
- Interpret the basic concepts of Logic
- Evaluate equations and inequalities, both algebraically and graphically
- Formulate the Weierstrass, Cauchy's and Chebychief's inequalities
- Calculate different mathematical problems of complex number
- Distinguish among Arithmetic, Geometric and Harmonic Series
- Interpret the ideas of the Summation of algebraic and trigonometric series
- Calculate the different problems of Theory of equations.
- Identify the idea about of De-Moiver's Theorem

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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.**

MAT102: Differential Calculus I

Course Code: MAT102 **Course Title: Differential Calculus I**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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 Content:

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:

Understand function both in mathematically and graphically
Understand the basic concepts of limit and continuity of function
Understand the basics of differentiation and techniques of differentiation
Understand some physical phenomena of differentiation
Solve some real life problems involving differentiation
Apply differentiation to analyze some properties of functions
Use differentiation to generate the idea of infinite series

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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.

MAT103: Analytic Geometry

Course Code: MAT103 **Course Title: Analytic Geometry**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

Course Objectives:

Upon completion of this course, students will be able to

1. Determine the equation of a line from given information.
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 Content:

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; Coplanarity; 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:

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

Identify isometries like reflections, rotations and translations and use them to categorize

conics. Define reflections, rotations and translations

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

Define conics and draw the graph of conics. Define circle, ellipse, hyperbola and parabola.
Express equations of line in the space. Express equation of the line a point and direction of which are given.
Describe equation of the line two points of which are given. Identify condition of perpendicular or parallel of two the lines.
Express equation of the line that passes through a point and perpendicular to two lines. Express equations of planes in the space

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.

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.
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.
Formulate equation of surfaces on Cartesian coordinates and locate any surface.
Express intersection curve of two surfaces, explain a sphere and express a cylinder.
Define ellipsoid and express hyperboloid of one and two sheets.

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** are to be answered.

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**.

MAT104: Linear Algebra I

Course Code: MAT104 **Course Title: Linear Algebra I**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

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.

Course Objectives:

Students enrolled in this course will

1. Work with the basic arithmetic operations on vectors and matrices, including inversion, using technology where appropriate.
2. Perform row operations and find echelon forms.
3. Learn to solve systems of linear equations and application problems requiring them. 4. Learn to compute determinants and know their properties.
5. Learn about and work with vector spaces and subspaces.
6. Learn about and work with linear transformations.
7. Learn to the basic terminology of linear algebra in Euclidean spaces, including linear independence, spanning, basis, rank, nullity.
8. Learn to find and use eigenvalues and eigenvectors of a matrix.
9. Learn about inner products and their uses.
10. Understand the axiomatic structure of a modern mathematical subject and learn to construct simple proofs.
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.
12. Use mathematically correct language and notation for Linear Algebra.
13. Become computational proficiency involving procedures in Linear Algebra.

Course Content:

1. **System of Linear Equations and Matrices:** 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.
2. **Euclidean Vector Spaces:** Vectors in $\mathbb{R}^{\mathbf{n}}$, 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:

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

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

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

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

Understand some applications of systems of linear equations.

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

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

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,

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

Calculate eigenvalues and their corresponding eigenspaces.

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.

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

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** are to be answered.

References:

1. H. Anton, and C. Rorres, **Linear Algebra with Applications**, 10th Edition.
2. S. Lipshutz, **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**, 3rd Edition.
5. B. Kolman & D. R. Hill, **Elementary Linear Algebra with Applications**, 9th Edition.

MAT105: Integral Calculus I Credits: 3

Course Code: MAT105 **Course Title: Integral Calculus I**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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:

In this course students will learn the basic ideas, tools and techniques of integral calculus and will use them to solve problems from real-life applications. In particular, students will learn

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 Content:

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*:**

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

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.

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.

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.

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.

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.

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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.

MAT150: Math Lab I (MATHEMATICA)
Credits: 3

Problems in the courses of First Year BS Honours will be solved using Computer Algebra System (CAS) **MATHEMATICA**.

Lab Assignments: Course instructors will provide a list of Lab assignments.

Course Learning Outcomes:

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

Understanding MATHEMATICA/ MATLAB/ FORTRAN/ C/ Mapple.
Apply any of the programing language in higher study
Solve real life problem using the programing language

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

MAT199: Viva Voce Credits: 2 Viva Voce on courses taught in the First Year.

List of Departmental and Non-Departmental Courses for Second Year (34 Credits) Effective for 2023-2024 onwards

Course No.	Course Name	Credits
MAT 201	Real Analysis I	3 credits
MAT 202	Differential Calculus II	3 credits
MAT 203	Ordinary Differential Equations I	3 credits
MAT 204	Linear Algebra II	3 credits
MAT 205	Integral Calculus II	3 credits
MAT 206	Numerical Analysis I	3 credits
MAT 207	Programming Fundamentals	3 credits
MAT 250	Math Lab II (MATLAB)	3 credits
MAT 299	Viva Voce	2 credits
	Total Major Credits	**26**
Non-Departmental Courses (8 credits). Choose any two Subjects from the following list		
	Physics 4 Credits Statistics 4 Credits Economics 4 Credits	
	Total Credits from Non-Departmental Courses	**8**
	Total Credits	**34**

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

MAT201: Real Analysis I

Course Code: MAT201 **Course Title: Real Analysis II**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

***Course Objectives*:**

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.

Course Contents:

1. **Real Numbers:** Bounded sets of real numbers. Supremum and infimum. The completeness axiom and its consequences. Dedekind's theorems. Cluster (limit) points; Bolzano-Weierstrass theorem.
2. **Sequence and Series:** 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.
3. **Continuity:** Properties of continuous functions. Intermediate value theorem.
4. **Differentiation:** Derivatives and its properties, Mean Value theorem, Taylor's theorem, Darboux's theorem.
5. **Integration:** 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.

Course Learning Outcomes:

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

Understand foundations of Number System.
Understand different properties of open sets and closed sets.
Learn the structure of the set of real numbers from the consequences of axiom of completeness.
Write formal proofs of different theories using logic in mathematical analysis.
Understand concept of limit, ideas of convergence of real sequence and series.
Test the convergence of series.
Rigorously understand continuity, differentiability of real valued function.
Learn Riemann integrability of a real function and their properties.
Understand relation between Darboux integral and Riemann integral.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours). 70 Marks. Eight questions of equal value will be set, of which any five 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.
5. M. Ramzan Ali Sarder, Elements of Real Analysis.

MAT202: Differential Calculus II

Course Code: MAT202 **Course Title: Differential Calculus II**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

***Course Objectives*:**
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.

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.

Course Content:

1. **Vector-valued functions of a single variable:** Limits, derivatives of vector valued functions.
2. **Tangent lines to graphs of vector-valued functions:** Arc length from vector view point. Arc length parametrization.
3. **Curvature of plane and space curves:** Curvature from intrinsic equations, Cartesian equations and parametric equations. Radius of curvature. Centre of curvature.
4. **Partial Differentiation:** 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.
5. **Extrema of functions of several variables:** Lagrange multipliers. Taylor's formula.
6. **Differentiation of Vectors:** Gradient, Divergence and curl and their physical meanings.

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

Develop a clear understanding of the fundamental concepts of vector calculus and partial derivatives.
Solve various problems using the basic concepts of vector calculus.
Visualize graphs of curve in 3D, surface and analyze various properties of them.
Apply ideas of partial derivatives in many real-life problems
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.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours). 70 Marks. **Eight** questions of equal value will be set, of which any **five** are to be answered.

References:

1. H. Anton, I.C. Bivens and S. Davis, **Calculus: Early Transcendentals,** Wiley (10^{th} 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,** Cengaga Learning.
5. R. Larson, R. P. Hostetler, F. H. Edwards and D. E. Heyd, **Calculus with Analytic Geometry,** Houghton Mifflin College Div.

MAT203: Ordinary Differential Equations I

Course Code: MAT203 **Course Title: Ordinary Differential Equations I**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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*:**

Students enrolled in this course will

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 Content:

1. **Ordinary differential equations and their solutions**. Initial value problems. Boundary value problems. Basic existence and uniqueness theorems (statement and illustration only).
2. **Solution of first order equations**. Separable equations and equations reducible to this form. Linear equations. Exact equations. Special integrating factors. Substitutions and transformations.
3. **Modeling with first order differential equations**. 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.

4. **Solution of higher order linear differential equations**. Solution space of homogeneous linear equations. Fundamental solutions of homogeneous equations. Reduction of order. Homogeneous linear equations with constant coefficients. Non-homogeneous equations. Method of undetermined coefficients. Variation of parameters. Cauchy-Euler differential equations.
5. **System of differential equations**, Linear system, Fundamental matrix. Solutions of linear systems with constant coefficient.

Course Learning Outcomes:

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

- Identify/classify differential equations by order, linearity, and homogeneity
- Solve first/higher order linear differential equations with and without initial conditions
- Determine regions of the plane over which a given order differential equation will have a unique solution
- Prepare for success in disciplines which rely on differential equations.
- 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
- Construct a second solution of a differential equation from a known solution
- Use methods for obtaining exact solutions of linear homogeneous and nonhomogeneous differential equation.
- Compare the methods of solutions developed in higher order and solution in 2^{nd} /1^{st} order equations.
- Name quantitative representations of solution to problems.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours). 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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

MAT204: Linear Algebra II

Course Code: MAT204 **Course Title: Linear Algebra II**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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 & 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.

Course Objectives:

Upon completion of this course, students will explore the followings

1. get familiar with the basic ideas and techniques of linear algebra for use in many other lecture courses
2. learn the fundamental concepts of linear algebra culminating in abstract vector spaces and linear transformations
3. understand abstract vector spaces over arbitrary fields and linear transformations, matrices, matrix algebra, similarity of matrices, inner product spaces
4. know some basic ideas of abstract algebra and techniques of proof which will be useful for future courses in pure mathematics

Course Content:

1. **Similar Matrices:** Canonical forms of matrices, Symmetric, orthogonal and Hermitian matrices
2. **Linear Functional and Dual Space:** 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
3. **Orthogonality:** 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

4. **Bilinear, Quadratic & Hermitian forms:** Matrix form; transformations; canonical forms; reduction form; definite and semi-definite forms; principal minors; and factorable forms
5. **Symmetric Matrices and Quadratic Forms:** Diagonalization of Symmetric Matrices; Quadratic Forms; The Singular Value Decomposition; Applications to Image Processing and Statistics
6. **Positive Definite Matrices:** Minima, Maxima, and Saddle Points; Tests for Positive Definiteness; Minimum Principles.

Course Learning Outcomes:

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

Know the concepts of similar and different types of matrices
Learn linear functional and dual spaces
Understand the concept of a linear transformation from one vector space to another and matrix representation
Learn how to calculate an orthogonal/orthonormal basis using Gram-Schmidt process
Know how to calculate Least-Squares solution and the Best Approximation
Know the concept and properties of Bilinear, Quadratic, Hermitian and Canonical form
Learn how to diagonalize a matrix
Determine positive definite matrix, maximum and minimum points
Know the application to Image Processing and in Statistics

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours). 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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. Lipshutz, 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.

MAT205: Integral Calculus II

Course Code: MAT205 **Course Title: Integral Calculus II**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

***Course Objectives*:**

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 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 Content:

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:

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

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours). 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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, Cengaga Learning. 5. W. Rudin, Principle of Mathematical Analysis.

MAT206: Numerical Analysis I

Course Code: MAT206 **Course Title: Numerical Analysis I**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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 Content:

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. **IVP for ODE:** Euler's and modified Euler's method, Runge-Kutta methods.

Course Learning Outcomes:

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

Students will learn the definition of Floating point.

To gather knowledge about different types of Error.

Students will learn about Algorithm and Convergence.

Learn how to find roots of an equation by using different root findings method.

Apply various techniques' to solve the system of linear equations using various numerical methods.

Explain and understand how to use Newton's divided difference technique.

Could apply Spine quadrature and adaptive quadrature in some real life problems.

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

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.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours). 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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

MAT 207: Programming Fundamentals

Course Code: MAT 207 **Course Title: Programming Fundamentals**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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 Content*:**

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:

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

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

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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.

MAT250: Math Lab II (MATLAB)

Problems in the courses of Second Year BS Honours will be solved using Computer Algebra System (CAS) **MATLAB**.

Course Learning Outcomes:

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

- Understanding MATHEMATICA/ MATLAB/ FORTRAN/ C/ Mapple.
- Apply any of the programing language in higher study
- Solve real life problem using the programing language

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

MAT299: Viva Voce Credits: 2 Viva Voce on courses taught in the Second Year.

List of Courses for Third Year
(32 credits)
Effective for 2024-2025 onwards

Course No.	Course Name	Credits
MAT 301	Real Analysis II	3 credits
MAT 302	Complex Analysis	3 credits
MAT 303	Ordinary Differential Equations II	3 credits
MAT 304	Abstract Algebra I : Theory of Groups	3 credits
MAT 305	Fundamentals of Topology	3 credits
MAT 306	Numerical Analysis II	3 credits
MAT 307	Mathematical Methods	3 credits
MAT 308	Optimizations	3 credits
MAT 309	Discrete Mathematics	3 credits
MAT 350	Math Lab III (FORTRAN)	3 credits
MAT 399	Viva Voce	2 credits
	Total Credits	**32**

MAT 301: Real Analysis II

Course Code: MAT 301 **Course Title: Real Analysis II**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

***Course Objectives*:**

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.

Course Content:

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.

1. **Sequence of Functions**: Pointwise and Uniform convergence. Interchangeability of limiting processes. Power series. Differentiation and integration of power series. Abel's continuity theorem.
2. **Metric Space**: Definition and examples. Open and closed sets, Equivalent metrics, Cauchy sequence and completeness, compactness.
3. **Differentiation**: Definition and properties of derivative a function of several variables, implicit, and inverse function theorems with some applications.
4. **Integration**: Definition and properties of the integral of functions of several variables, Fubini's theorem, and Change of variables.

Course Learning Outcomes:

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

- Elementary topological properties of a metric space.
- Success of infinite sequence and series of functions defined of a metric space.
- Elementary analysis of functions of several variables. Limit, continuity, differentiability of a function, for example.
- Applications of partial derivatives in optimization of a function.
- Applications of inverse and implicit function theorem.

Evaluation of multiple integrals using Fubini's theorem.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours) 70 Marks. **Eight** questions will be set, of which any **five** 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.

MAT 302: Complex Analysis

Course Code: MAT 302 **Course Title: Complex Analysis**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

Course Objectives:

1. To develop the basic ideas complex numbers and functions.
2. To learn the ideas of limit, continuity and differentiability of complex functions, theorems related to differentiation of complex function.
3. Understanding the Harmonic function, Analytic function and Cauchy-Riemann equation.
4. Learning the basic properties of integration of complex functions, theorems on complex integration and use of these theorems to solving mathematical problems.

5. Understanding the ideas of Taylor and Laurent series and the singularities.

6. Understanding the basics of Conformal mapping and Bilinear transformation.

Course Content:

1. **Complex Plane:** Metric properties and geometry of the complex plane. The point at infinity. Stereographic projection.
2. **Functions of a Complex Variable:** Limit, continuity and differentiability of a complex function. Analytic functions and their properties. Harmonic functions.
3. **Complex Integration:** Line integration over rectifiable curves. Winding number. Cauchy's theorem. Cauchy's integral formula. Liouville's theorem. Fundamental theorem of Algebra. Rouche's theorem. The maximum and the minimum modulus principle.
4. **Singularities:** 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.
5. **Bilinear transformations and mappings:** Basic mapping. Linear fractional transformations. Other mappings. Conformal mappings.

Course Learning Outcomes:

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

Understand complex numbers and complex functions.

Understand the basic concepts of limit, continuity and differentiability of complex function

Understand the analytic function and Cauchy-Riemann equation

Understand the integration of complex functions and theorems related to complex integration

Solve some difficult integration using the theorems involving complex function

Understand the infinite series and singularities

Understand the ideas of Conformal mapping and Bilinear transformation.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours) 70 Marks. **Eight** questions will be set, of which any f**ive** 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. Spigel, Complex Variables, Schaums Outline Series.

MAT 303: Ordinary Differential Equations II

Course Code: MAT 303 **Course Title: Ordinary Differential Equations II**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale Rationale:

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.

Course Objectives:

Students enrolled in this course will

1. understand the existence and uniqueness of solution of initial value problem
2. learn to identify the type of critical points of 2D system
3. learn about series solutions of differential equations with constant and variable coefficients
4. learn about generating function, recurrence relations and orthogonality relations
5. learn about Gamma function, Error function and Hyper geometric equation

Course Content:

1. **Existence and uniqueness theory:** 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).
2. **Stability Analysis of 2D System**: Phase Plane. Critical Points. Stability of linear and nonlinear systems differential equations. Limit Cycles and Periodic Solutions.
3. **Series solutions of second order linear equations:** Taylor series solutions about an ordinary point. Frobenius series solutions about regular singular points.
4. **Bessel functions**: Generating function, recurrence relations, Bessel differential equation, Integral representations Orthogonality relations, Modified Bessel functions.
5. **Legendre functions**: 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.
6. **Chebyshev function**: Chebyshev differential equation, Chebyshev Polynomials, Generating function, recurrence relations, Approximation of Functions by Chebyshev Polynomials
7. **Special functions:** Gamma function. Error function. Hyper geometric equation, special hyper geometric function, Generalized hyper geometric function, special confluent hyperbolic functions.

Course Learning Outcomes:

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

Explain the foundations of mathematics

Interpret the basic concepts of Logic

Evaluate equations and inequalities, both algebraically and graphically
Formulate the Weierstrass, Cauchy's and Chebychief's inequalities
Calculate different mathematical problems of complex number
Distinguish among Arithmetic, Geometric and Harmonic Series

Interpret the ideas of the Summation of algebraic and trigonometric series
Calculate the different problems of Theory of equations.
Identify the idea about of De-Moiver's Theorem

Evaluation*:* Incourse Assessment 30 Marks. Final examination (Theory, 3 hours). 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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.

MAT 304: Abstract Algebra I: Theory of Groups

Course Code: MAT 304 **Course Title: Abstract Algebra I: Theory of Groups**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 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 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 Content:

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.

Course Learning Outcomes:

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

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.

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

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.

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.

Construct a Cayley table for a group.
Demonstrate familiarity with the common groups.
Compute the order of a group, the order of a subgroup, and the order of an element.
Identify subgroups of a given group.
Identify cyclic groups and apply the fundamental theorem of cyclic groups.
Demonstrate familiarity with permutation groups and be able to decompose permutations into 2- cycles.
Define the concepts of homomorphism, isomorphism, and automorphism and check whether a given function defines one of these.
Prove the common properties of homomorphism.
Define the external direct product and be able to compute the direct product of groups.
Apply Lagrange's theorem.
Define normal subgroups and be able to prove that given subgroups are normal.
State and apply the fundamental theorem of finite Abelian groups.
Give a definition of ring and cite a variety of common examples and non-examples (finite and infinite, polynomials, and matrices).
Give the definition of field and cite a variety of common examples and non-examples.

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** uestions of equal value will be set, of which any **five** are to be answered.

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.

MAT 305: Fundamentals of Topology

Course Code: MAT 305 **Course Title: Fundamentals of Topology**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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*:**

The objectives of this course are to

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

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

Distinguish among open and closed sets on different topological spaces;
Identify precisely when a collection of subsets of a given set equipped with a topology forms a topological space;
Construct maps between topological spaces to understand when two topological spaces are homeomorphic;
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
Determine that a given point in a topological space is either a limit point or not for a given subset of a topological space;
Apply and use fixed point theorems to understand modern day applications apply theoretical concepts in topology to understand real world applications.

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** ıestions of equal value will be set, of which any **five** 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

MAT 306: Numerical Analysis II

Course Code: MAT 306 **Course Title: Numerical Analysis II**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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.

This course helps to understand the solution techniques of Parabolic, Elliptic, and Hyperbolic PDEs

Course Contents:

1. **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
2. **Approximating Eigenvalues**: Eigenvalues and eigenvectors, Power method, Householder's method, Q-R method.
3. **Nonlinear System of Equations**: Fixed point for functions of several variables, Newton's method, Quasi-Newton's method. Steepest Descent techniques.
4. **BVP for ODE:** Shooting method for linear and nonlinear problems, Finite difference methods for linear and nonlinear 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, Basics in **Elliptic and Hyperbolic PDEs**.

***Course Learning Outcomes*:**

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

Explain the foundations of mathematics

Interpret the basic concepts of Logic

Evaluate equations and inequalities, both algebraically and graphically
Formulate the Weierstrass, Cauchy's and Chebychief's inequalities
Calculate different mathematical problems of complex number
Distinguish among Arithmetic, Geometric and Harmonic Series

Interpret the ideas of the Summation of algebraic and trigonometric series
Calculate the different problems of Theory of equations.
Identify the idea about of De-Moiver's Theorem

Evaluation:Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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.

MAT 307: Mathematical Methods

Course Code: MAT 307 **Course Title: Mathematical Methods**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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-Liouvile 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 it's applications
5. To learn the finding of eigenvalues and eigenfunctions by solving Strum-Liouvile boundary value problem (S-LBVP), formation of Green's function from S-LBVP and hence the solving of S-LBVP.

Course Content:

1. **Fourier Series:** Fourier series and its convergence. Fourier sine and cosine series. Properties of Fourier series. Operations on Fourier series. Complex from. 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 Strum-Liouvile boundary value problems:** Regular Strum-Liouville boundary value problems. Non-homogeneous boundary value problems and the Fredholm alternative. Solution by eigenfunction expansion. Green's functions. Singular Strum Liouville boundary value problems/Oscillation and comparison theory.

***Course Learning Outcomes*:**

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

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

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.

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

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

Find the solution of the wave, heat flow and Laplace equations using the Fourier transforms

Solve integral equation.

Find the eigenvalues and the corresponding eigenfunctions by solving Strum-Liouvil boundary value problems.

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

Find the Green's function from Strum-Liouvile boundary value problems.

Solve Strum-Liouvile boundary value problems by finding the Green's function from Strum Liouvile boundary value problems.

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** uestions of equal value will be set, of which any **five** are to be answered.

References:

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

MAT 308: Optimizations

Course Code: MAT 308 **Course Title: Optimizations**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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 extend 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.

Special focus will be given on the formulation and solution procedures of real-life problems.

Course Content:

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:

Describe the basic properties such as convex sets and related theorems;

Gather knowledge about LP, standard form, canonical form, slack variables, surplus variables, basic solutions, non-basic solutions, feasible solutions optimal solutions etc.;

Know the ways to formulate a real life problem into a mathematical problem;

Solve 2-dimensional problems by using graphical method;

Solve general LP problems by using simplex method (usual simplex method, 2-phase simplex method and Big-M simplex method);

Solve special type of LP by Dual simplex method;

Use sensitivity analysis to study the changes in availability, conditions etc.

Solve NLP problems by different optimization methods

Solve QP problems by different methods.

Evaluation: In-course Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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.

MAT 309: Discrete Mathematics

Course Code: MAT 309 **Course Title: Discrete Mathematics**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

***Course Objectives*:**

1. To give knowledge on some basic mathematical concepts in discrete mathematics and their applications.

2. To provide brief knowledge of use of logical inferences, different methods of proofs. 3. To introduce elementary graph theory and some algorithms of computational mathematics. 4. Students will learn about the bridging of discrete mathematics with computer science.

***Course Content*:**

1. **Mathematical reasoning:** Inference and fallacies; methods of proof; complexity of algorithms; recursive definitions.
2. **Counting:** Counting principles; inclusion-exclusion principle; pigeonhole principle; generating functions; recurrence relations; applications to computer operations.
3. **Graphs and Trees:** Introduction to graphs, paths and trees; structure and symmetry of graphs; paths and connectivity; Eulerian and Hamiltonian paths; directed graphs; shortest path problems: Dijkstra'a 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.
4. **Boolean Algebra:** Boolean functions; logic gates; minimization of circuits.

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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 Strictures, 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.

MAT 350: Math Lab III (FORTRAN)

Problems in the courses of Third Year BS Honours will be solved using Programming Language **FORTRAN**.

Lab Assignments: Course instructors will provide a list of Lab assignments.

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

Course Learning Outcomes:

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

Understanding MATHEMATICA/ MATLAB/ FORTRAN/ C/ Mapple.
Apply any of the programing language in higher study
Solve real life problem using the programing language

MAT 399: Viva Voce Credits: 2 Viva Voce on courses taught in the Third Year.

List of Courses for Fourth Year

(35 credits)
Effective for 2025-2026 onwards

Course No.	Course Name	Credits
MAT 401	Introduction to Functional Analysis	Credit 3
MAT 402	Partial Differential Equations	Credit 3
MAT 403	Differential Geometry and Tensor Calculus	Credit 3
MAT 404	Abstract Algebra II : Theory of Rings and Modules	Credit 3
MAT 405	Mechanics	Credit 3
MAT 406	Hydrodynamics	Credit 3
MAT 407	Introduction to Number Theory	Credits 3
Take any three from the following courses (**MAT 408 - MAT 412**)		
MAT 408	Fuzzy Mathematics	Credit 3
MAT 409	Population Dynamics	Credit 3
MAT 410	Lattice Theory	Credit 3
MTH 411	Difference Equations	Credit 3
MAT 412	Introduction to Actuarial Mathematics	Credit 3
MAT 450	Math Lab IV	Credit 3
MAT 499	Viva-voce	Credit 2
	Total Credits	**35**

MTH 401: Introduction to Functional Analysis			
Course Code: MTH-401 **Course Title: Introduction to Functional Analysis**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

Course Objectives:

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.

Learning Outcomes:

Upon completion of this course, students will explore the followings:

1. Familiarity with the main, big theorems of functional analysis.
2. Learn the fundamental concepts of Topological Linear Spaces and study of the properties of bounded linear maps between topological linear spaces of various kinds.
3. Ability to use duality in various contexts and theoretical results from the course in concrete situations.
4. Capacity to work with families of applications appearing in the course, particularly specific calculations needed in the context of famous theorem.
5. Be able to produce examples and counter examples illustrating the mathematical concepts presented in the course.
6. Understand the statements and proofs of important theorems and be able to explain the key steps in proofs, sometimes with variation.

Course Content:

1. **Review of General Linear (Vector) spaces:** 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.
2. **Inner product and norm (on a vector space over $\mathbb{R}$):** 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.

3. **Normed linear spaces:** Sequence space, separability, Riesz's lemma, boundedness and continuity, Quotient space, spaces of bounded linear operators.
4. **Banach spaces:** 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.
5. **Hilbert spaces:** Basic properties, Riesz representation theorem, adjoint of a linear operator.

Course Learning Outcomes:

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

Familiarity with the main, big theorems of functional analysis.

Learn the fundamental concepts of Topological Linear Spaces and study of the properties of bounded linear maps between topological linear spaces of various kinds.
Ability to use duality in various contexts and theoretical results from the course in concrete situations.
Capacity to work with families of applications appearing in the course, particularly specific calculations needed in the context of famous theorem.
Be able to produce examples and counter examples illustrating the mathematical concepts presented in the course.
Understand the statements and proofs of important theorems and be able to explain the key steps in proofs, sometimes with variation.

Evaluation: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any Five 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

MAT 402: Partial Differential Equations			
Course Code: MAT 402 **Course Title:Partial Differential Equations**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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:

The main objective of the course is for students to

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 Content:

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:

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

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

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

Explain Conservation laws and shock waves; The eikonal equation; General nonlinear equations.
Classify second order linear partial differential equations

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

Learn basics of Fourier analysis

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

Discuss solutions techniques for parabolic PDEs, formulate maximum principles for various equations and derive consequences

Interpret Solutions techniques for Laplace and Poissons equations

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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.

MAT 403: Differential Geometry and Tensor Calculus			
Course Code: MAT 403 **Course Title: Differential Geometry and Tensor Calculus**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

Course Objectives:

1. To give knowledge on mathematical concepts of space curve and surfaces, this course is very much useful.
2. Students will know the concepts of helices, tangent, normal, bi-normal, involutes and evolutes.
3. Students will learn about the fundamental forms, Gaussian and normal Curvature, Geodesics etc. on mathematical concepts of surface.
4. Student will have knowledge on Christoffel's symbols and their applications, Riemann Christoffel tenser and the Ricci tensor.

Course Content:

Differential Geometry

1. **Curves in Space:** 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).
2. **Serret-Frenet's Formulae:** Curvature, Torsion, Helices, Spherical Indicatrix of tangent, etc. Involutes, Evolutes, Bertrand curves.

3. **Vector Functions of Two Variables:** Tangent and normal plane to the surface. Principal normal, binormal and Fundamental planes, theorems on curvature and torsion.

4. **Elementary Theory of Surfaces:** 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. \

5. **Second Fundamental Form:** 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-Ennerper. The equation of Gauss-Weingarten.

Tensor Calculus

1. **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.
2. **Covariant Differentiation:** Covariant derivatives, The Riemann-Christoffel tenser and the Ricci tensor, the zero tensor, Intrinsic derivative, Bianchi identity, Covariant curvature tensor, Flat Space.

Course Learning Outcomes:

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

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

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

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

Gather knowledge about Spherical indicatrix of tangent, normal, binormal, **c**urvature and torsion.

Illustrate curves of involutes and evolutes and Bertrand curves.

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

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

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

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

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** (at least **ONE** from Group B) are to be answered.

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. Lispchutz**, 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.

MAT 404: Abstract Algebra II: Theory of Rings and Modules

Course Code: MAT 404 **Course Title: Abstract Algebra II: Theory of Rings and Modules**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

A ring is an important fundamental concept in algebra and includes integers, polynomials and matrices as some of the basic examples. Ring theory has applications in number theory and geometry. A module over a ring is a generalization of vector space over a field. The study of modules over a ring $\boldsymbol{R}$ provides us with an insight into the structure of $\boldsymbol{R}$. In this course we shall develop ring and module theory leading to the fundamental theorems of Wedderburn and some of its applications.

Course Objectives:

By the end of the course the student should understand:

1. The importance of rings and modules as central objects in algebra and some of its applications.
2. The basic structure and theory of rings and modules.
3. How to develop this theory to investigate important classes of integral domains.
4. The concept of a module as a generalization of a vector space and an Abelian group.
5. The classification of any finitely generated module as a homomorphic image of a free module.
6. Simple modules, Schur's lemma. Radical, simple and semi simple artinian rings. Examples.
7. Semi-simple modules, artinian modules, their endomorphism. Examples.
8. The Wedderburn-Artin theorem.

Learning Outcomes:

Upon successful completion of this course students will be able to:

1. Understand the central role of abstract algebra in modern mathematics.
2. See the relations between algebra and its applications in and outside mathematics.
3. Become familiar with rings and fields, and understand the structure theory of modules over a Euclidean domain along with its implications.
4. Write precise and accurate mathematical definitions of objects in ring theory.
5. Use mathematical definitions to identify and construct examples and to distinguish examples from non-examples.
6. Validate and critically assess a mathematical proof.
7. To understand how every finitely generated module is a homomorphic image of a free module.
8. Use a combination of theoretical knowledge and independent mathematical thinking to investigate questions in ring theory and to construct proofs.
9. Write about ring theory in a coherent, grammatically correct and technically accurate manner.

Course Contents:

1. **Some Topics in the Theory of Rings:** Polynomial rings over Unique Factorization Domain (UFD), Wedderburn's and Jacobson's Theorems, the Radical, Semisimple and Simple rings.
2. **Rings of Fractions:** Rings of fractions and embedding theorems, local rings and Noetherian rings, Rings with Ore conditions and related theorems.
3. **Field Theory:** Irreducible Polynomials and Eisenstein criterion, Algebraic extensions of fields, Splitting fields and Finite fields.
4. **Modules and vector spaces:** Definition and examples, submodules and direct sums, R-homomorphisms and quotient modules, completely reducible and free modules, projective and injective modules, Noetherian and Artinian rings and modules. Wedderburn-Artin theorem.

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 4 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** are to be answered.

References:

1. Hiram Paley and Paul M. Weichsel. A First Course in Abstract Algebra, Holt, Rinehart and Winston
2. S Lang, Algebra, Springer
3. Thomas W Hungerford, Algebra, Springer
4. P.B. Bhattarcharya, S.K. Jain & S.R. Nagpaul, Basic Abstract Algebra, Cambridge University Press
5. David S. Dummit, Richard M. Foote, Abstract Algebra, 3rd edition, John Wiley & Sons, Inc.

MAT 405: Mechanics			
Course Code: MAT 405 **Course Title: Mechanics**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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 Content:

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:

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

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.

Further, general formulae for the determination of the centre of gravity and formulate for the centre of gravity by integration.

Definitions of stable and unstable equilibriums with examples.

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.

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

Learning 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.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** (at least **TWO** from each group) are to be answered.

***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 lnternational

MAT 406: Hydrodynamics			
Course Code: MAT 406 **Course Title: Hydrodynamics**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

Course Objectives:

1. To understand the concept of fluid and to be able to explain the properties of fluid. 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.
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. 4. To understand the concept of dimensional analysis and to be able to apply it in a specific situation. 5. To understand about the Navier-Stokes equation, steady and unsteady laminar flow.

Course Content:

Hydrodynamics

1. **Preliminaries:** 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.
2. **Continuous Motion:** 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.
3. **Two-Dimensional Flow:** 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.
4. **Circle Theorem and Complex Dynamics:** The circle's theorem; motion of a circular cylinder; pressure at points on a circular cylinder; application of circle theorem. Blasius theorem; Sources, sinks and doublets; complex potential and complex velocity; stagnation points.

Course Learning Outcomes:

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

- Learn equations of continuity and Euler's equation of motion
- Gather knowledge about Bernoulli's equations and its application
- Know about circulation and vorticity
- Acquire knowledge about sources, sinks and doublets
- Learn the basic knowledge on fluid properties
- Know the Navier-Stokes equations of motion of a viscous fluid
- Study the dimensional analysis
- Derive the exact solutions of steady and unsteady plane flows
- Analyze Prandtl's boundary layer equations in many problems

Evaluation: Incourse Assessment 30 Marks. Final exam (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which **five** are to be answered taking at least **two** from each group.

***References*:**

1. **L.M. Mine Thomosn**, 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 407: Introduction to Number Theory

Course Code: MTH 407 **Course Title: Introduction to Number Theory**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2022-2023**

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 Content:

1. **Divisibility:** Definition; properties; division algorithm; greatest integer function.
2. **Primes:** Definition, Euclid's Theorem; Prime Number Theorem (statement only); Goldbachand 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. **Arithmetic Functions:** 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.

Course Learning Outcomes:

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

Effectively express the concepts and results of Number Theory.

Understand the logic and methods behind the major theorems and their proofs in Number Theory.

Construct mathematical proofs of statements and look for counter examples to establish falsity of some the statements.

Understand and verify the conjectures about the natural numbers.

Use concepts of number theory to solve huge number of real life problems.

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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.

MAT 408: Fuzzy Mathematics			
Course Code: MAT 408 **Course Title: Fuzzy Mathematics**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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 Content:

1. **Crisp sets and fuzzy sets :** An overview of crisps sets; the notion of fuzzy sets; basic concepts of fuzzy sets. An overview of classical logic; fuzzy logic.
2. **Operations of fuzzy sets :** General discussion; fuzzy complement; fuzzy union; fuzzy intersection combinations of operations; general aggregation operations.
3. **Fuzzy Arithmetic :** fuzzy numbers, linguistic variables, arithmetic operations on intervals and fuzzy numbers, lattice of fuzzy numbers, fuzzy equations.
4. **Fuzzy relations :** Crisp and fuzzy relations ; binary relations on a set; equivalence and similarity relations; compatibility or tolerance relations; orderings; morphisms; fuzzy relational equations.
5. **Applications of Fuzzy Set Theory**.

Course Learning Outcomes:

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

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

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.

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

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

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

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

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

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 3 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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

MAT 409: Population Dynamics			
Course Code: MAT 409 **Course Title: Population Dynamics**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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:

The main objective of the course is that students

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

Course Content:

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:

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

Explain the modeling concepts
Single species population modeling idea
Single species with harvesting and application
Multispecies population and interaction concepts
Competitive population dynamics and scenario
Discrete disease problems and their clarification for population
Communicable disease modeling and application
Infectious disease and their qualitative analysis
Optimal controlling strategy and its significance.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight questions** will be set of which any **five** 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 410: Lattice Theory

Course Code: MTH-410 **Course Title: Lattice Theory**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

Lattice theory is the study of sets of objects known as lattice. It is an outgrowth of Boolean Algebra and it provides a frame work for unifying the study of ordered sets in mathematics. One of the most important practical applications and also one of the oldest applications of lattice theory is the use of Boolean Algebra in modeling and simplifying switching circuits. The prime feature of lattice theory is its versatility. It connects many areas like Algebra, analysis, topology, logic, computer science, combinatorics, linear algebra, geometry, category theory, probability etc.

Course Objectives:

1. To give knowledge on fundamentals of lattices e.g. relations, ordered sets, maxima and minima of sets, meet and join of elements of a lattice, Hasse diagram etc.
2. To know modular lattice, its properties and related theorems.
3. To know modular and distributive lattices, their properties and related theorems.
4. To know metric lattice, its properties and related theorems.
5. To know complemented lattice, its properties and related theorems.
6. To know about Boolean Algebra and canonical form of Boolean Algebra.
7. To know the application of Boolean Algebra in formulating and simplifying switching circuits.

Course Content:

1. Lattice: Definitions and elementary properties.
2. Modular Lattices and applications in Abstract Algebra.
3. Metric Lattices and distributive Lattices.
4. Reducibility and independence.
5. Complemented Lattices.
6. Boolean Algebra.
7. Canonical form of a Boolean Algebra.

Learning Outcomes: After learning the course, the students will be able to-

1. explain poset, lattice and their fundamental properties with examples.
2. represent a lattice with the help of Hasse diagram.
3. explain modular and distributive lattices with examples and how their properties work.
4. explain metric as well as complemented lattices and their properties.
5. formulate Boolean functions, switching circuits.
6. simplify switching circuits using Boolean Algebra.

Evaluation: Incourse Assessment: 30 Marks. Final examination (Theory, 4 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **Five** are to be answered.

References:

1. G. H. Hardy and E. M. Wright, An introduction to the theory of numbers, Oxford University Press
2. S. Rose, A course in Number Theory, Oxford University Press
3. P. Samuel, Algebraic Theory of Numbers, Dover Publications

MTH 411: Difference Equations

Course Code: MTH-411 **Course Title: Difference Equations**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Course Content:

1. Review of calculus of differences. Difference equations: Basic terminology, definition and simple examples, Formation of difference equations, Discrete analogy to differential equations, order and degree of a difference equation.
2. Homogeneous Linear difference equations (constant coefficient equations and their solutions, linear dependence and independence, initial value and boundary value problems, reduction of order, Euler equation, generating functions, eigenvalue problems).
3. Inhomogeneous linear difference equations (operator methods, variation of parameters, reduction of order, method of undetermined coefficients).
4. Linear difference equations with variable coefficients and their solutions.
5. Simple nonlinear difference equations; pseudo-nonlinear equations. The Z-transform and it use in solving difference equations.
6. Differential-difference equations. Extension of difference equation to functions of a continuous variable. Partial difference equations.
7. Modelling with difference equations. Simple applications (application to vibrating systems, electrical networks, beams, collisions, probability, the Fibonacci numbers, integration, geometry, determinants, power series solutions, investigation of special functions, biology). Commercial applications (simple interest, compound interest, annuities). Application to chaos, Julia sets and the Mandelbrot set.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 3 hours). 70 Marks Eight questions of equal value will be set, of which any five are to be answered.

References

1. H. Levy & F. Lessman , Finite Difference Equations.
2. N. Finizio & G. Ladas, An Introduction to Differential Equations with Difference Equations.
3. Murray R. Spiegel, Theory and Problems of Calculus of Finite Differences and Difference Equations.
4. Frank Chorlton, Ordinary Differential and Difference Equations Theory and Applications.

MTH 412: Introduction to Actuarial Mathematics

Course Code: MTH-412 **Course Title: Introduction to Actuarial Mathematics**	**Credit Hours: 3.00 Hrs/Week** **Total Marks: 100**	**Year: First**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

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.

Course Objectives:

At the end of the course students will

1. Have sufficient exposure to actuarial and financial mathematics
2. Be familiar with the role of insurance in society, basic economic theory, and the basics of how insurance and financial markets operate.
3. Have familiarity with several of the technical tools, computer languages or software packages used by actuaries.
4. Develop communication, leadership and teamwork skills, and understand their importance in the actuarial industry.
5. Be able to apply this knowledge and these skills in new combinations and to new problems.

Course Content:

1. **Theory of Interest:** Interest, Simple Interest, Compound Interest, Accumulated Value, Present Value, Rate of Discount: d, Constant Force of Interest: δ, Varying Force of Interest.
2. **Annuities and its Applications:** 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.
3. **Individual Risk Models:** Models for Individual Claim Random Variables, Sums of Independent Random Variables, Approximations for the Distribution of the Sum, and Applications to Insurance. 4. **Survival Distributions:** Probability for the Age-at-Death, The Survival Function, Time-Until Death for a Person Aged x, Curtate-Future-Lifetime, Force of Mortality.
5. **Life Tables:** 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.
6. **Life Insurance:** Introduction, Insurance payable at the moment of death, Insurance payable at the end of the year of death, Recursion equations, Commutation Functions.
7. **Life Annuities:** 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.
8. **Net Premium:** Fully continuous premiums, Fully discrete premiums, True mthly Payment Premiums, commutation functions, and Apportionable premiums.

Course Learning Outcomes (CLOs):

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

Compute different types of interests which is the most important learning for a business student.

Will calculate annuities and their application in life insurance.
Different types of risk model will give clear idea about the formulation of policy.
Learn how to use mortality tables to calculate commutation function.
Will learn how to calculate life annuities
Learn how to use mortality tables to calculate different types of life assurances.
Net premium calculation will give advantage to find out the benefit of both the company and the policy owner.

***Evaluation**:* Incourse Assessment 30 Marks. Final examination (Theory, 3 hours). 70 Marks. **Eight** ıestions of equal value will be set, of which any **five** 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.

MAT 450: Math Lab IV

Credit: 3

Problem Solving in concurrent courses using any programming language: MATHEMATICA/ MATLAB/ FORTRAN/ C/ Mapple.

Lab Assignments: Course instructors will provide a list of Lab assignments.

Course Learning Outcomes:

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

Understanding MATHEMATICA/ MATLAB/ FORTRAN/ C/ Mapple.
Apply any of the programing language in higher study
Solve real life problem using the programing language

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

MAT 499: Viva Voce

Credit: 2

Viva Voce on all the courses taught at 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.

Department of Mathematics
Affiliated Colleges
Four-Year BS Honours Programme
(Effective for 2022 -2023)

List of Non-Departmental Courses for 1st Year BS (Honours)
Mathematics Courses for Honours Students of the Departments other than Mathematics

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

First Year Minor

Course NO.	Course Names	Credits
MAM101	Fundamentals of Mathematics	2 credits
MAM102	Calculus I	2 credits
MAM103	Analytic and Vector Geometry	2 credits
MAM104	Linear Algebra	2 credits

Detailed Syllabi

Course Code: MAM101 Credit: 2.0 Year: lst Type: Theory Course

Course Title: Fundamentals of Mathematics

Rationale:

Fundamentals of mathematics are the base of all mathematics courses. After completion of this course, students will get some useful and applicable ideas on mathematical logic, methods of proofs, set theory, relations and functions with graphs, real and complex number system, inequality, summation of series, some very important theories on roots of polynomials.

Course Objectives:

1. This course will help students to learn set theory, real and complex number system and inequality.
2. To give a clear idea on the relations, functions and graphs of functions in considerable detail.
3. To give some interesting idea on roots of polynomials.
4. To teach the students how to obtain summation of a finite series.

Course Content:

1. **Sets Theory and Functions:** Sets and subsets. Set operations. Family of Sets. De Morgan's laws. Relations and functions: Cartesian product of sets. Relations. Equivalence relations. Functions. Images and inverse images of sets. Injective, surjective, and bijective functions. Inverse functions.
2. **The Real number system:** Field and order properties. Natural numbers, integers and rational numbers. Absolute value. Basic inequalities. (including inequalities involving means, powers; inequalities of Cauchy, Chebyshev, Weierstrass).
3. **The Complex number system:** Geometrical representation Polar form. De Moivre's theorem and its applications. Elementary number theory: Divisibility. Fundamental theorem of arithmetic. Congruences (basic properties only).
4. **Summation of finite series:** Arithmetic-geometric series. Method of difference. Successive differences.
5. **Theory of equations:** Synthetic division. Number of roots of polynomial equations. Relations between roots and coefficients. Multiplicity of roots. Symmetric functions of roots. Transformation of equations.

***Course Learning Outcomes*:**

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

Explain the foundations of mathematics

Interpret the basic concepts of Logic

Evaluate equations and inequalities, both algebraically and graphically
Formulate the Weierstrass, Cauchy's and Chebychief's inequalities
Calculate different mathematical problems of complex number
Distinguish among Arithmetic, Geometric and Harmonic Series

Interpret the ideas of the Summation of algebraic and trigonometric series
Calculate the different problems of Theory of equations.

Identify the idea about of De-Moiver's Theorem

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 2 ½ hours). 70 Marks **Eight** questions of equal value will be set, of which any **five** are to be answered.

Text Books:

1. S. Lipschutz, **Set Theory,** Schaum's Outline Series.
2. S. Barnard & J. M. Child, **Higher Algebra**, Macmillan and Co.
3. W.L. Ferrar, **Algebra**, Oxford University Press
4. P.R. Halmos, Naive, **Set Theory**, Springer-Verlag
5. Murray R Spiegel, **Vector Analysis**, Schaum's Outline Series**.**

Course Code: MAM102 Credit Hour: 2.0 Year: lst Type: Theory Course

Course Title: Calculus I

Rationale:

This course deals with the study of rates of change and provides a framework for modeling systems in which there is change and way to deduce the predictions of such models. Here we study two types of calculus: Differential calculus and integral calculus for single variable functions. Differential calculus controls the rate of change of a quantity whereas integral calculus discoveries the quantity where the rate of change is known. The course Calculus-I covers topics of differential and integral calculus including limits and continuity, higher-order derivatives, curve sketching, differentials, indefinite and definite integrals (areas, arc lengths and volumes) and applications of derivatives and integrals.

Course Objectives:

1. Establish the fundamental theorems and applications of the calculus of single variable functions.
2. Explore the concepts, properties, and aspects of the differential and integral calculus of single variable functions.
3. To learn about the application derivatives to analyze and sketch the graph of a function, to solve applied derivative related problems, to solve applied minimum and maximum problems. 4. To learn the basic ideas and properties of integration
5. Understanding the techniques of integration and using them to solve the real life oriented problems such as length, area, volume and surface areas.

Course Content:

A. Differential Calculus

1. Functions and their graphs (polynomial and rational functions, logarithmic and exponential functions, trigonometric functions and their inverses, hyperbolic functions and their inverses, combination of such functions).
2. Limits of Functions: definition.. Basic limit theorems (without proofs). Limit at infinity and infinite

limits. Continuous functions. Properties Continuous functions on closed and boundary intervals (no proofs required).

3. Differentiation: Tangent lines and rates of change. Definition of derivative. One-sided derivatives. Rules of differentiation (with applications). Linear approximations and differentials. Successive differentiation. Leibnitz theorem. Rolle's theorem: Lagrange's mean value theorems. Extrema of functions, problems involving maxima and minima.

B. Integral Calculus

4. Integrals: Antiderivatives and indefinite integrals. Techniques of integration. Definite integration using antiderivatives.

5. Definite integral as a limit of a sum. The fundamental theorem of calculus. Integration by reduction.

6. Application of integration: Plane areas. Solids of revolution. Volumes by cylindrical shells. Volumes by cross-sections. Arc length and surface of revolution.

Course Learning Outcomes:

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

Understand function both in mathematically and graphically
Understand the basic concepts of limit and continuity of function
Understand the basics of differentiation and techniques of differentiation
Understand some physical phenomena of differentiation
Solve some real life problems involving differentiation
Apply differentiation to analyze some properties of functions
Use differentiation to generate the idea of infinite series

Evaluation: Incourse Assessment: 30 marks. Final examination (Theory, 2 ½ hours): 70 Marks. **Eight** questions of equal value will be set of which **five** are to be answered, taking at least **two** questions from each group.

Text Books:

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. 8. J. Stewart, **Single Variable Calculus: Early Transcendentals**, Cengage Learning.
4. R. Larson, R. P. Hostetler, F. H. Edwards and D. E. Heyd, **Calculus with Analytic Geometry**, Houghton Mifflin College Div.

Course Code: MAM103 Credit: 2.0 Year: lst Type: Theory Course

Course Title: Analytic and Vector Geometry

Rationale:

Analytic Geometry is a branch of algebra that is used to represent geometric objects - points, straight lines, planes and conics being the most basic of these. Our goal is to develop skills on 2- dimensional and 3-dimensional geometry which includes theory and some real life applications problems on coordinate systems, conic sections, pair of straight lines, planes and lines, conicoids. After finishing this course, students will able to explain the physical meaning of graphs, geometrical formula and equations. Also students will relate the theory with the real world phenomena.

Course Objectives:

1. To give knowledge on representation and evaluation basic mathematical information verbally, numerically, graphically, and symbolically.
2. Students will able to gather concepts of coordinates systems (both in 2D and 3D), transformation of axes, pair of straight lines, conics (in 2D and 3D), lines and planes.
3. To interpret mathematical models such as formulas, graphs, algebraic equations, real life problem and draw conclusion from them.
4. Students will learn about the theory and proofs of derived formulas and ideas with considerable interest.

Course Content:

Two-dimensional geometry

1. Coordinates in two dimension. Transformations of coordinates.
2. Reduction of second degree equations to standard forms. Pairs of straight lines. Identifications of conics and pair of straight lines. Equations of conics in polar coordinates.

Three-dimensional geometry

3. Coordinates in three dimensions. Direction cosines, and direction ratios.
4. Planes, straight lines and conicoids (basic definitions and properties only)

Vector geometry

1. Vectors in plane and space. Algebra of vectors. Scalar and vector products. Triple scalar products. Applications to Geometry.
2.

Course Learning Outcomes:

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

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

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

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

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

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

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

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.

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.

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.

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

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

Define ellipsoid and express hyperboloid of one and two sheets.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 2 ½ hours). 70 Marks

Eight questions of equal value will be set, of which any **five** are to be answered.

Text Books:

1. A.F.M. Abdur Rahman& P.K. Bhattacharjee, **Analytic Geometry and Vector Analysis**.
2. Khosh Mohammad, **Analytic Geometry and Vector Analysis**.
3. J. A. Hummel, **Vector Geometry**.
4. H. Anton, I. C. Bivens and S. Davis, **Calculus: Early Transcendentals**, Wiley.
5. J.G. Chakravarty and P.R. Ghosh, **Advanced Analytical Geometry**.

Course Code: MAM104 Credit: 2.0 Year: lst Type: Theory Course

Course Title: Linear Algebra

Rationale:

Linear algebra is an essential part of the curriculum of majors such as: Computer science, Engineering, Economics, Physics, Chemistry 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. In an increasingly complex world, mathematical thinking, understanding, and skill are more important than ever. This course will show students how to simplify many types of complex problems using matrix algebra and vector geometry. Students who major in the sciences or engineering are often required to study linear algebra. This course provides a solid foundation for further study in mathematics, the sciences, and engineering.

***Course Objectives*:**

Linear Algebra plays a significant role in many areas of mathematics, statistics, engineering, the natural Sciences, Economics and the computer sciences. Students who major in these fields will need some familiarity with linear algebra and its applications. This course supports the following goals:

1. Engage students in sound mathematical thinking and reasoning. This should include students finding patterns, generalizing, and asking/answering relevant questions.

2. Provide a setting that prepares students to read and learn mathematics on their own. 3. Explore multiple representations of topics including graphical, symbolic, numerical, oral, and written.

4. Encourage students to make connections among the various representations to gain a richer, more flexible understanding of each concept.

5. Analyze the structure of real-world problems and plan solution strategies. Solve the problems using appropriate tools.

6. Develop a mathematical vocabulary by expressing mathematical ideas orally and in writing. **7.** Enhance and reinforce the student's understanding of concepts through the use of technology when appropriate.

Course Content:

1. **Matrices and Determinants:** Notion of matrix. Types of matrices. Matrix operations, laws of matrix Algebra. Determinant function. Properties of determinants. Minors, Cofactors, expansion and evaluation of determinants. Elementary row and column operations and row-reduced echelon matrices. Invertible matrices. Block matrices.
2. **System of Linear Equations:** Linear equations. System of linear equations (homogeneous and non-homogeneous)and their solutions. Application of matrices and determinants for solving system of linear equations.
3. **Vector Spaces:** Vectors in $R^n$and C^n: Review of geometric vectors in $R^2$and R^3space. Vectors in $R^n$and C^n. Inner product. Norm and distance in $R^n$and C^n. Abstract vector space over R and C. Subspace. Sum and direct sum of sub spaces. Linear independence of vectors; basis and dimension of vector spaces. Row and column space of a matrix; rank of matrices. Solution spaces of systems of linear equation.
4. **Linear transformations**. Kernel and image of a linear transformation and their properties. Matrix representation of linear transformations. Change of bases.
5. **Eigenvalues and eigenvectors.** Diagonalization. Cayley Hamiton theorem. Applications.

Course Learning Outcomes:

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

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

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

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

Understand some applications of systems of linear equations.

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

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

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

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

Find the kernel, range, rank, and nullity of a linear transformation.
Calculate eigenvalues and their corresponding eigenspaces.
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.
Determine if a matrix is diagonalizable, and if it is, how to diagonalize it.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 2 ½ hours). 70 Marks **Eight** questions of equal value will be set, of which any **five** are to be answered

Text Books:

1. H. Anton, and C.Rorres, **Linear Algebra with Applications**, Wiley
2. David C. Lay, **Linear Algebra and Its Applications**, Pearson
3. S. Lipshutz, **Linear Algebra**, Schaum's Outline Series.
4. B Kolman and D R. HilL, **Elementary Linear Algebra with Applications**, Pearson Education, Inc.

University of Dhaka

Department of Mathematics
Four Year B. S. Honours Programme

(Effective for 2022-2023, 2023-2024)

List of Non-Departmental Courses for 2nd Year BS (Honours)

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

MAM201 Mathematical Analysis	2 credits
MAM202 Calculus II	2 credits
MAM203 Ordinary Differential Equation	2 credits
MAM204 Numerical Analysis	2 credits
MAM205 Mathematical Methods	2 credits
MAM206 Elementary Linear Algebra	2 credits

Detailed Syllabi

Course Code: MAM201 Credit: 2.0 Year: 2nd Type: Theory Course

Course Title: Mathematical Analysis

Rationale:

Mathematical analysis is the branch of mathematics dealing with limits and related theories, such as differentiation, integration, measure, infinite series, and analytic functions. These theories are usually studied in the context of real and complex numbers and functions. Analysis evolved from calculus, which involves the elementary concepts and techniques of analysis. Analysis may be distinguished from geometry; however, it can be applied to any space of mathematical objects that has a definition of nearness (a topological space) or specific distances between objects (a metric space). Mathematical analysis is what mathematicians would call the rigorous version of calculus. Mathematical analysis is typically the first course in a pure math curriculum, because it introduces you to the important ideas and methodologies of pure math in the context of material you are already familiar with.

Course Objectives:

After completing this course, students should have developed a clear understanding of the fundamental concepts of Mathematical Analysis.

Students will develop the following skills:

1. Have the knowledge of basic properties of the field of real numbers.
2. Have the knowledge of the series of real numbers and convergence.
3. Studying Bolzano –Weirstrass theorem and Cauchy criteria.
4. Studying the basic topological properties of the real numbers.
5. Have the knowledge of real functions-limits of functions and their properties.
6. Studying the notion of continuous functions and their properties.
7. Studying the differentiability of real functions and related theorems.

Course Content:

1. Bounded sets of real numbers. Supremum and infimum. The completeness axiom and its consequences. Dedekind's theorems. Cluster (limit) points; Bolzano-Weierstrass theorem. 2. Infinite sequences. Convergence. Theorems on limits. Monotone sequences, subsequences. Cauchy's general principle of convergence.

3. 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. 4. Properties of continuous functions. Intermediate value theorem.

5. The derivative : standard theorems (with proofs)

6. The Riemann integral; definitions via Riemann's sums and Darboux's sums. Darboux's theorem. (equivalence of the two definitions) Necessary and sufficient conditions for integrability. Classes of integrable functions. Fundamental theorem of calculus. Improper integrals: Tests for convergence.

Course Learning Outcomes:

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

Explain the foundations of mathematics

Interpret the basic concepts of Logic

Evaluate equations and inequalities, both algebraically and graphically

Formulate the Weierstrass, Cauchy's and Chebychief's inequalities
Calculate different mathematical problems of complex number
Distinguish among Arithmetic, Geometric and Harmonic Series

Interpret the ideas of the Summation of algebraic and trigonometric series
Calculate the different problems of Theory of equations.
Identify the idea about of De-Moiver's Theorem

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 2 ½ hours). 70 Marks
Eight questions of equal value will be set, of which any five are to be answered.

References:

1. K. A. Ross : Elementary Analysis : The Theory of Calculus.
2. R. G. Bartle, & D. R. Sherbert : Introduction to Real Analysis.
3. W. Rudin : Principles of Mathematical Analysis.
4. M. Ramzan Ali Sarder : Elements of Real Analysis.

Course Code: MAM202 Credit: 2.0 Year: 2nd Type: Theory Course

Course Title: Calculus II

Rationale:
Multi-variable calculus is the extension of calculus to more than one variable. Single variable calculus is a highly geometric subject and multivariable calculus is the same, maybe even more so. In calculus class, student's studied the graphs of functions z =f(x, y) and w = f(x, y, z) and learned to relate derivatives and integrals to these graphs. One key difference is that more variables mean more geometric dimensions. This makes visualization of graphs both harder and more rewarding and useful.

Course Objectives:
After completing this course, students should have developed a clear understanding of the fundamental concepts of multivariable calculus.

Students will develop the following skills:

1. Fluency with vector operations and the various ways to describe vector valued functions.
2. An understanding of a parametric curve described by a position vector; the ability to find parametric equations of a curve and to compute its velocity and acceleration vectors.
3. A comprehensive understanding of the gradient, including its relationship to level curves (or surfaces), directional derivatives, and linear approximation.
4. The ability to compute derivatives using the chain rule or total differentials. 12. The ability to set up and solve optimization problems involving several variables, with or without constraints.
5. An understanding of line integrals for work and flux, surface integrals for flux, general surface integrals and volume integrals. Also, an understanding of the physical interpretation of these integrals.
6. The ability to set up and compute multiple integrals in rectangular, polar, cylindrical and spherical coordinates.
7. The ability to change variables in multiple integrals.
8. An understanding of the major theorems (Green's, Stokes', Gauss') of the course and of some physical applications of these theorems.

Course Content:

Differential Calculus:

1. **Quadratic surfaces:** Quadratic surfaces, Techniques for graphing quadratic surfaces, translation and reflection of quadratic surfaces.
2. **Vector valued function:** Parametric curves, Vector valued functions, Graphs, Vector form of a line segment, Limits and continuity, Derivatives, Tangent lines, Anti-derivatives, Arc length, Parameterizations, Unit tangent vector, Unit normal vector, Unit binormal vector, Curvature, Velocity, acceleration and speed, Tangential scalar and vector component of accelerations, Normal scalar and vector component of accelerations. Model of projectile motion.
3. **Partial derivatives:** Functions of two or more variables, Domain and graphs, Level curves, Limits and continuity, Partial derivatives, Differentiability, Differentials, Local linear approximations, Chain rule, Implicit differentiation, Directional derivatives and gradients, Tangent plane and normal vector, Extrema of functions of two variables, Extreme value theorem, Relative and absolute extrema, Lagrange multipliers, Constrained-extremum principle for three variables and one constraint.

Integral Calculus:

1. **Double integral:** Volume, Fubini's Theorem for rectangular region, Double integral for non rectangular region, Area as a double integral, Double integral in polar coordinates, Surface area. 2. **Triple integral:** Fubini's Theorem for rectangular box, Volume, Triple integral in Cylindrical and Spherical coordinates.
3. **Change of variables:** Jacobian in 2 and 3 variables, Change of variables for double and triple integrals.
4. **Vector calculus:** Line integrals, Surface integrals, Volume integrals, Green's theorem, Divergence theorem and Stoke's theorem with examples.

Learning Outcomes:

By the end of MTM 202: Calculus II, students should be able to:

1. Students will be able to sketch the graphs of functions of double variables, especially quadric surfaces.
2. Students will learn the basic analysis (limit, continuity, partial differentiation, and differentiability) of several variables' functions.
3. Students will be able to compute the dynamical properties of vector valued functions and their geometric properties like length, curvature, and torsion.
4. Students will be able to compute integrals of several variable functions to compute area and volume of irregular shapes bounded by the graphs of functions and interprets them in the context of different branches of natural sciences.
5. Students will be able to compute the extreme values of a function/model of several variables defined on compact domain using the ideas of partial derivatives.
6. Students will be able to compute the integral of the tangential components of a vector field along a curve specially in $\mathbf{R}^2$ and $\mathbf{R}^3$, to compute the flux density, flux across a closed surface, circulation density, and circulation of a vector field along the boundary of a surface for vector fields.

Course Learning Outcomes:

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

Sketch the graphs of functions of double variables, especially quadric surfaces.
Gain knowledge on the basic analysis of functions of several variables (limit, continuity, partial differentiation, and differentiability).
Compute the dynamical properties of vector valued functions and their geometric properties like

length, curvature, and torsion.
Change the parameter for a parametric curve to a different parameter and investigate issues associated with changes of parameter.
Compute the extreme values of a function/model of several variables defined on compact domain using the ideas of partial derivatives.
Compute integrals of several variable functions to compute area and volume of irregular shapes bounded by the graphs of functions and interprets them in the context of different branches of natural sciences.
Evaluate triple integrals using Cartesian, cylindrical and spherical coordinate system and will be able to change a problem from one coordinate system to another.
Calculate the Jacobian of a function of multiple variables and will be able to evaluate double and triple integrals applying changes of variables
Compute the integral of the tangential components of a vector field along a curve especially in $\mathbb{R}^2$ and $\mathbb{R}^3$, to compute the flux density, flux across a closed surface, circulation density, and circulation of a vector field along the boundary of a surface for vector fields.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 2 ½ hours): 70 Marks
Eight questions of equal value will be set, of which any five are to be answered.

References:

1. Calculus by Anton, Bivens and Davis. 10^{th} Edition.
2. Multivariable Calculus by James Stewart, 7^{th} Edition.
3. Calculus by Dennis G. Zill and Warren S. Wright, Fourth Edition.

Course Code: MAM203 Credit: 2.0 Year: 2^{nd} Type: Theory Course

Course Title: Ordinary Differential Equations

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:
Students enrolled in this course will

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 Content:

1. **Ordinary differential equations and their solutions**. Initial value problems. Boundary value problems. Basic existence and uniqueness theorems (statement and illustration only).
2. **Solution of first order equations**. Separable equations and equations reducible to this form. Linear equations. Exact equations. Special integrating factors. Substitutions and transformations.
3. **Modeling with first order differential equations**. 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.
4. **Solution of higher order linear differential equations**. Solution space of homogeneous linear equations. Fundamental solutions of homogeneous equations. Reduction of order. Homogeneous linear equations with constant coefficients. Non-homogeneous equations. Method of undetermined coefficients. Variation of parameters. Cauchy-Euler differential equations.
5. **System of differential equations**, Linear system, Fundamental matrix. Solutions of linear systems with constant coefficient.

Course Learning Outcomes:

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

Identify/classify differential equations by order, linearity, and homogeneity
Solve first/higher order linear differential equations with and without initial conditions
Determine regions of the plane over which a given order differential equation will have a unique solution
Prepare for success in disciplines which rely on differential equations.
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
Construct a second solution of a differential equation from a known solution
Use methods for obtaining exact solutions of linear homogeneous and nonhomogeneous differential equation.
Compare the methods of solutions developed in higher order and solution in 2^{nd} /1^{st} order equations.
Name quantitative representations of solution to problems.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 2 ½ hours): 70 Marks
Eight questions of equal value will be set, of which any five 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

Course Code: MAM204 Credit: 2.0 Year: 2^{nd} Type: Theory Course

Course Title: Numerical Analysis

Rationale:

Numerical analysis, area of mathematics and computer science that creates, analyzes, and implements algorithmsfor obtaining numerical solutions to problems involving continuous variables. Such problems arise throughout the natural sciences, social sciences, engineering, medicine, and business. Numerical analysis is concerned with all aspects of the numerical solution of a problem, from the theoretical development and understanding of numerical methods to their practical implementation as reliable and efficient computer programs. Most numerical analysts specialize in small subfields, but they share some common concerns, perspectives, and mathematical methods of analysis.

Course Objectives:

Students enrolled in this course will:

1. Learn the solution procedure of equation in one variable, error analysis for the iterative methods and their convergences.
2. Learn some interpolation and extrapolation methods
3. Provide numerical methods of solving differentiation and integration.
4. Solve system of linear equations with Gaussian elimination method, Matrix inversion, LU decomposition method.
5. Develop the basic understanding of numerical algorithms and skills to implement algorithms to solve mathematical problems on the computer.

Course Content:

1. **The solution of equation in one variable:** Bisection algorithm, Method of false position. Fixed point iteration, Newton-Raphson method, Error Analysis for iterative method, Acceleration of convergence.
2. **Interpolation and polynomial approximation:** Taylor polynomials, Interpolation and Lagrange polynomial, Iterated interpolation, Extrapolation.
3. **Differentiation and Integration:** Numerical differentiation, Richardson's extrapolation, Elements of Numerical Integration, Adaptive quadrature method, Romberg's integration, Gaussian quadrature.
4. **Solutions of linear systems:** Gaussian elimination and backward substitution, pivoting strategies, Matrix inversion; LU decomposition method.

Course Learning Outcomes:

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

Find out the root of an equation by using different methods.
Do numerical differentiation and integration by using different rules.
Find the solution of the initial value problem (IVP) by using different methods.
Solve system of linear equations by various methods.

To design and analyze numerical techniques to approximate solutions to problems for which finding a closed-form (analytic) solution is not possible.
Learn about interpolation and extrapolation polynomials.
Derive different types of solution of numerical problems.
Apply numerical methods to obtain approximate solutions to mathematical problems.
Analyze and evaluate the accuracy of common numerical methods.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 2 ½ hours). 70 Marks
Eight questions of equal value will be set, of which any **five** 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. Store and R. Bulirsch, Introduction to Numerical Analysis, Springer-Verlag, ISBN 0-387-90420

Course Code: MAM205 Credit: 2.0 Year: 2nd Type: Theory Course

Course Title: Mathematical Methods

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, Beta and Gamma functions 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 the complex integration; Cauchy's theorem and Cauchy's integral formula. Singularities and residues. Cauchy's residue theorem. Evaluation of real integrals using contour integration.

Course Content:
1. **Fourier Series**: Fourier Series, Fourier sine and cosine series. Properties of Fourier series. Operations on Fourier series. Complex form.
2. **Solution of differential equations in infinite series:** Equations of Legendre, Bessel, Hermite and Laguerre. Special functions: Legendre, Hermite and Laguerre polynomials; Bessel functions. Generating functiions and recurrenc relations.
3. **Beta and Gamma functions**.
4. **Laplace transforms**: Basic definitions and properties, Existence theorem.. Laplace transforms of periodic functions. Transforms of convolutions. Inverse transform. Use of Lablace transforms in sol ving initial value problems.
5. **Functions of a complex variable:** analytic functions. Complex integration; Cauchy's theorem and Cauchy's integral formula. Singularities and residues. Cauchy's residue theorem. Evaluation of real integrals using contour integration.

Course Learning Outcomes:
After successfully completing MTM 205: Mathematical Methods, students should be able to

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

Apply Fourier series expansion of periodic function of one variable to selected physical problems.
Understand the concept of Laplace transform and inverse Laplace transform of various function.
Solve initial value problems and boundary value problems using Laplace transform.
Calculate the Fourier transforms of simple functions and apply them to selected physical problems.
Find the solution of the wave, heat flow and Laplace equations using the Fourier transforms 7.
Solve integral equation.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 2 ½ hours). 70 Marks
Eight questions of equal value will be set, of which any five are to be answered.

References:

1. W.N. Lebedev & R.A. Silverman, Special Functions and their Applications.
2. E. Kreuszig, Advanced Engineering Mathematics.
3. M. R. Spiegel, Laplace Transforms, Schaum's Outline Series.
4. R.V. Churchill & J. W. Brown, Complex Variables and Applications.

Course Code: MAM206 Credit: 2.0 Year: 2nd Type: Theory Course

Course Title: Elementary Linear Algebra

Rationale:

Linear algebra is a branch of mathematics that studies systems of linear equations and their representations in vector spaces and through matrices. The concepts of linear algebra are extremely useful in physics, economics and social sciences, natural sciences, and engineering. Due to its broad range of applications, linear algebra is one of the most widely taught subjects in university level mathematics.

Course Objectives:

Linear algebra is about linear combinations. That is, using arithmetic on columns of numbers called vectors and arrays of numbers called matrices, to create new columns and arrays of numbers. Linear algebra is the study of lines and planes, vector spaces and mappings that are required for linear transforms and it has several sides: computational techniques, concepts, and applications. Main goal is to help students to master all of these facets of the subject and to see the interplay among them.

Course Content:

1. **Matrices and Determinants:** Notion of matrix. Types of matrices. Matrix operations, laws of matrix Algebra. Determinant function. Properties of determinants. Minors, Cofactors, expansion and evaluation of determinants. Elementary row and column operations and row-reduced echelon matrices. Invertible matrices.
2. **System of Linear Equations:** Introduction to system of Linear equations. Homogeneous and non-homogeneous equations. Gaussian and Gauss-Jordan eliminations. Application of matrices and determinants for solving system of linear equations. Cramer's rule.
3. **Vector in $\boldsymbol{R^n}$:** Review of geometric vectors in $\boldsymbol{R}^2$ and $\boldsymbol{R}^3$ space. Vectors in $\boldsymbol{R^n}$. Inner product, Norm and distance in $\boldsymbol{R^n}$, orthogonality, geometric interpretation of a system of linear equations, cross product.
4. **Real vector space and linear transformations**: Axiomatic formulation of an abstract real vector space, vector subspaces, span, linear independence, coordinates and basis, dimension of a real vector space, tensor product and direct sum of vector spaces, change of basis, row space, column space and null space, rank, nullity, rank-nullity theorem.
5. **Spectral analysis of linear transformations:** Eigenvalues and eigenvectors, degeneracy, diagonalization, Caley Hamilton theorem, symmetric matrices and quadratic form, Jordan canonical form.
6. **Complex vector space:** Vectors in $\boldsymbol{C}^n$, complex Euclidean inner product and norm, Complex Eigenvalues and Eigenvectors, Hermitian, unitary and normal matrices, finding Eigenvalues and Eigen-vectors of Hermitian matrices, unitary diagonalization of a Hermitian matrix.

Course Learning Outcomes:

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

Perform operations with matrices and find the transpose and inverse of a matrix.
Calculate determinants using row operations, column operations and expansion down any column and across any row.
Solve systems of linear equations and homogeneous systems of linear equations by Gaussian elimination and Gauss-Jordan elimination.
Understand some applications of systems of linear equations.
Interpret vectors in two and three-dimensional space both algebraically and geometrically.
Recognize the concepts of the terms span, linear independence, basis, and dimension, and apply these concepts to various vector spaces and subspaces
Find the kernel, range, rank, and nullity of a linear transformation.
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.
Determine if a matrix is diagonalizable, and if it is, how to diagonalize it. Calculate eigenvalues and the corresponding eigenspaces.

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 2 ½ hours): 70 Marks Eight questions of equal value will be set, of which any five are to be answered.

References:

1. H. Anton & C. Rorres, John-Wiley & Sons, Elementary Linear Algebra: Applications Version.
2. David C. Lay, Addison Wesley, Linear Algebra and Its Applications.
3. David Poole, Linear Algebra: A Modern Introduction
4. Linear Algebra - S. Lipshutz, Schaum’s Outline Series.