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

List of Departmental & Non- Departmental Courses for First Year (31 credits)

(Effective from 2020-2021 onwards)

Departmental Courses (23 credits)

MTH 101	Fundamentals of Mathematics	3 credits
MTH 102	Differential Calculus I	3 credits
MTH 103	Analytic Geometry	3 credits
MTH 104	Linear Algebra I	3 credits
MTH 105	Integral Calculus I	3 credits
MTH 106	Introduction to Number Theory	3 credits
MTH 150	Math Lab I (MATHEMATICA)	3 credits
MTH 199	Viva Voce	2 credits

Non-Departmental Courses (8 credits)

Physics

PM 111	Waves and Mechanics	2 credits
PM 122	Electricity and Magnetism	2 credits

Statistics

Stat M 101	Introduction to Statistics	2 credits
Stat M 102	Introduction to Probability	2 credits

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

MTH 101: Fundamentals of Mathematics **Credits: 3**

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.

Learning Outcomes:

After completing the course students will be able to

1. describe mathematical statements, propositions and truth table
2. gather knowledge about basic proof methods and apply these methods to prove various

propositions
3. apply set theory on some physical problems
4. identify the basic properties of the real number system
5. solve some elementary inequalities
6. explain relations and functions and with their relationship
7. illustrate different types of functions and their inverses
8. understand various properties and tests for graphs of functions
9. identify the complex number system with some elementary properties
10. find roots of various of polynomial equations and form equations with given conditions
11. find summations of different algebraic and trigonometric series
12. gather knowledge about vectors and their applications.

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.**

MTH 102: Differential Calculus I **Credits: 3**

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: Notion, representation and transformation of graphs of functions; Different kinds of functions (polynomial, rational, logarithmic, exponential, trigonometric, hyperbolic functions), their inverses and graphs; Combination of functions; Even and odd functions; Symmetricity of functions; Functional model.

2. Limit and Continuity: Limit of a function; Basic limit theorems with proofs; Limit at infinity and infinite limit; Sandwich (Squeezing) theorem (without proof);Continuous and discontinuous functions; Algebra of continuous functions; Properties of continuous functions on closed, and bounded intervals; Horizontal and vertical asymptotes; Intermediate Value Theorem (statement and illustration with applications).

3. Differentiation: Tangent lines and rates of change; Derivative of a function, One sided derivatives; Techniques of differentiation; Chain rule theorem (without proof); 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; Exponential models; 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.

Learning Outcomes:

1. Understand function both in mathematically and graphically
2. Understand the basic concepts of limit and continuity of function
3. Understand the basics of differentiation and techniques of differentiation
4. Understand some physical phenomena of differentiation
5. Solve some real life problems involving differentiation
6. Apply differentiation to analyze some properties of functions
7. 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.

MTH 103: Analytic Geometry **Credits: 3**

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.

Learning Outcomes:

On completion of the course, the student will be able to

1. Identify isometries like reflections, rotations and translations and use them to categorize conics. Define reflections, rotations and translations.
2. Apply these notions to curves. Use isometries to transform conics to canonic forms.
3. Define conics and draw the graph of conics. Define circle, ellipse, hyperbola and parabola.
4. Express equations of line in the space. Express equation of the line a point and direction of

which are given.

5. Describe equation of the line two points of which are given.Identify condition of perpendicular or parallel of two the lines.
6. Express equation of the line that passes through a point and perpendicular to two lines.Express equations of planes in the space.
7. 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.
8. 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.
9. Calculate distance from a point to a line, distance from a line to a line, distance from a point to a plane anddefine surfaces.
10. Formulate equation of surfaces on Cartesian coordinates and locate any surface.
11. Express intersection curve of two surfaces,explain a sphere and express a cylinder.
12. 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**.

MTH 104: Linear Algebra I **Credits: 3**

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. **Matrices and Determinants:**Review of matrices and determinant; Elementary row and column operations; Row-reduced echelon matrices; Invertible matrices; Block matrices. Application to Leontief input-output Economic models, Markov chains and Computer graphics.
2. **System of Linear Equations:** Linear equations; System of linear equations (homogeneous and non-homogeneous); Solutions of system of linear equations using different method; Application to Network Flow and Electrical Networks, Balancing chemical equations; Polynomial interpolation.
3. **Vectors in $\mathbb{R}^{\mathbf{n}}$ and $\mathbb{C}^{\mathbf{n}}$:** Review of geometric vectors in $\mathbb{R}^{2}$ and $\mathbb{R}^{3}$ space. Vectors in $\mathbb{R}^{\mathbf{n}}$and$\mathbb{C}^{\mathbf{n}}$, Inner product. Norm and distance in $\mathbb{R}^{\mathbf{n}}$and$\mathbb{C}^{\mathbf{n}}$, respectively.
4. **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.
5. **Linear Transformations:** Linear transformations; Examples and illustrations with applications; Kernel and image of a linear transformation and their properties.
6. **Eigenvalues and Eigenvectors of Matrices:** Eigenvalues and eigenvectors; Diagonalization; Cayley-Hamilton theorem; Application to Least square approximation.

Learning Outcomes:

By the end of Linear Algebra I, students should be able to

1. Solve systems of linear equations and homogeneous systems of linear equations by Gaussian elimination and Gauss-Jordan elimination.
2. Row-reduce a matrix to either row-echelon or reduced row-echelon form.
3. Use matrix operations to solve systems of equations and be able to determine the nature of the solutions.
4. Understand some applications of systems of linear equations.

5. Perform operations with matrices and find the transpose and inverse of a matrix.
6. Calculate determinants using row operations, column operations and expansion down any column and across any row.
7. Interpret vectors in two and three-dimensional space both algebraically and geometrically.
8. Recognize the concepts of the terms span, linear independence, basis, and dimension, and apply these concepts to various vector spaces and subspaces,
9. Find the kernel, range, rank, and nullity of a linear transformation.
10. Calculate eigenvalues and their corresponding eigenspaces.
11. 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.
12. 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.

MTH 105: Integral Calculus I **Credits: 3**

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. **Introduction:** 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:** Area between curves; 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 Physical 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 coordinates; Tangent lines, arc length and area for Polar Curves; Area and volume of surface by revolving in Polar coordinates.

***Learning Outcomes*:**

1. 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.
2. 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.
3. 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.
4. 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.
5. 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.

MTH 106: Introduction to Number Theory **Credits: 3**

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); Goldbach and Twin Primes conjectures; Fermat primes; Fermat's Theorem; Mersenne primes.
3. **Fundamental Theorem of Arithmetic:** Definition and properties of greatest common divisor (GCD) and least common multiple (LCM); Euclid's algorithm; Linear combinations; Linear Diophantine equations; Continued Fractions; Euclid's Lemma; Canonical prime factorization; divisibility; GCD; and LCM in terms of prime factorizations; Pseudoprimes and Carmichael.
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; Application of congruence(Round robin tournaments).
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; Euclid’s theorem.

Learning Outcomes:

Students enrolled in this course will

1. Effectively express the concepts and results of Number Theory.
2. Understand the logic and methods behind the major theorems and their proofs in Number Theory.
3. Construct mathematical proofs of statements and look for counter examples to establish falsity of some the statements.
4. Understand and verify the conjectures about the natural numbers.
5. 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.

MTH 150: Math Lab I (MATHEMATICA) Credits: 3

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

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

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

MTH 199: Viva Voce Credits: 2

Viva Voce on courses taught in the First Year.

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

List of Departmental & Non- Departmental Courses for Second Year (33 credits)

(Effective from 2020-2021 onwards)

Departmental Courses (29 credits)

MTH 201	Real Analysis I	3 credits
MTH 202	Differential Calculus II	3 credits
MTH 203	Ordinary Differential Equations I	3 credits
MTH 204	Linear Algebra	3 credits
MTH 205	Integral Calculus II	3 credits
MTH 206	Numerical Analysis I	3 credits
MTH 207	Discrete Mathematics	3 credits
MTH 208	Programming Fundamentals	3 credits
MTH 250	Math Lab II (MATLAB)	3 credits
MTH 299	Viva Voce	2 credits

Non-Departmental Courses (4 credits)

Statistics

Stat M 201	Principles of Statistics	2 credits
Stat M 202	Mathematical Statistics I	2 credits

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

MTH 201: Real Analysis I   Credits: 3

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 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. Cauchy's first and second theorems on limits.
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 (with proofs). Intermediate value theorem.
5. The derivative: standard theorems including Darboux's theorem.
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.

***Learning Outcomes*:**

After completion of the course students will learn the structure of the real from the consequences of axiom of completeness, concept of limit, ideas of convergence of real sequence and series. Using the concepts of limit and convergence of sequence, students will be able to rigorously understand continuity, differentiability and Riemann integrability of a real function and their properties. Students will be used to writing formal proof in mathematical analysis.

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.

MTH 202: Differential Calculus II **Credits: 3**

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 know about the Tangent lines to graphs of vector-valued functions, Arc length from vector view point. Arc length parametrization. Finally, the students will know how to apply this knowledge in many 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.

Learning Outcomes:

Upon successful completion of the course, students should be able to

1. developed a clear understanding of the fundamental concepts of vector calculus and partial

derivatives
2. solve various problems using the basic concepts of vector calculus
3. visualize graphs of curve in 3D, surface and analyze various properties of them
4. apply ideas of partial derivatives in many real life problems
5. find extreme values of multivariable functions using different approaches and apply them to solve practical problems
6. 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 (10th Edition).
2. E.W. Swokowski, **Calculus with Analytic Geometry,** Brooks/Cole.
3. G.B. Thomas and R. L. Finney, **Calculus and Analytic Geometry**, Addison Wesley.
4. J. Stewart, **Multi VariableCalculus: 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.

MTH 203: Ordinary Differential Equations I **Credits: 3**

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 Physicsmodeled by first and second order differential equations

Course Content:

1. **Ordinary differential equations and their solutions**: Classification of differential equations. Solutions. Implicit solutions. Singular solutions. Initial and Boundary value problems. Basic existence and uniqueness theorems (statement and illustration only). Direction fields and Phase plane.
2. **Solution of first order equations**: Separable equations. Linear equations, Exact equations, Integrating factors, Substitutions and transformations.
3. **Modelling 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**: Linear differential operators. Basic theory of linear differential equations. Solution space of homogeneous linear equations. Fundamental solutions of homogeneous equations. Reduction of order. Homogeneous and Non-homogeneous linear equations with constant coefficients. Method of undetermined coefficients and variation of parameters. Inverse operators. Cauchy-Euler differential equations.
5. **Modelling with second-order equations**: Vibration of a mass on a spring, free and undamped motion; free and damped motion; forced motion; resonance phenomena; electric circuit problems, motion of a rocket.

***Learning Outcomes*:**

Upon completion of this course, the student should be able to

1. classify differential equations by order, linearity, and homogeneity
2. solve first order linear differential equationswith and without initial conditions
3. determine regions of the plane over which a given first-order differential equation will have a unique solution
4. solve homogeneous linear equations with constant coefficients
5. use the method of undetermined coefficients and variation of parameters to solve differential equations
6. determine if a set of functions is linearly dependent or independent by definition and by using the Wronskian
7. construct a second solution of a differential equation from a known solution
8. usethe method to solve differential equationswith variable coefficients
9. 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 first and secondorder differential equations
10. interpret and present graphical and qualitative representations of solutions to problems modeled by differential 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. S. L. Ross, Differential Equations, John Wiley and Sons

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

MTH 204: Linear Algebra II **Credits: 3**

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.

***Learning Outcomes*:**

On successful completion of this course unit students will be able to

1. know and use the properties of similar matrices. Also, explain the concepts of canonical forms of matrices, Symmetric, orthogonal and Hermitian matrices
2. get familiar with the Linear Functional, dual Space, Second dual space, Annihilators, Transpose of a linear transformation and their properties
3. 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
4. describe the basic terminologies appeared in inner product spaces and the Gram-Schmidt process and gather knowledge about operator theory and apply them into the spectral theorem
5. formulate the concept and properties of Bilinear, Quadratic &Hermitian forms and demonstrate them into canonical forms and identify the definite, semi-definite forms and minors
6. deal with the Diagonalization process, and to recognize their applications
7. learn several ways of testing for positive definiteness and also how to find Minima, Maxima, and Saddle Points by the entries of *A*
8. apply linear algebra to such real world phenomena as to Image Processing and Statistics, and linear Models and Fourier Approximation.

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.

MTH 205: Integral Calculus II **Credits: 3**

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 as a double integral, Double integrals in polar form.
2. **Triple integrals and iterated integrals:** Volume as a triple integral, Triple integral in cylindrical and spherical coordinates.
3. 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:** Test for convergence.
6. Integrals depending upon a parameter. Differentiation and integration under the integral sign.

Learning Outcomes:

1. The ability to work with different types of coordinate systems like rectangular coordinates, cylindrical coordinates and spherical coordinates.
2. The ability to understand and to sketch, roughly, different types of cylindrical and quadric surfaces.
3. The ability to set up and compute multiple integrals in rectangular, polar, cylindrical and spherical coordinates.
4. The ability to change variables in multiple integrals.
5. An understanding of physical significance of gradient, divergence and curl.
6. 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.
7. An understanding of the major theorems (Green's, Stokes', Gauss') of the course and of some physical applications of these theorems.

8. The ability to test the convergence of improper integrals.
9. Adequate knowledge of 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.

MTH 206:Numerical Analysis I **Credits: 3**

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. **Solution of equation in one variable:** Bisection algorithm, Method of false position. Fixed point iteration, Newton-Raphson method, Error Analysis for iterative method, Accelerating limit of

convergence.
2. **Interpolation and polynomial approximation**: Taylor polynomials, Interpolation and Lagrange polynomial, Iterated interpolation, Richardson's extrapolation.
3. **Differentiation and Integration**: Numerical differentiation, Elements of Numerical Integration, Adaptive quadrature method, Romberg's integration, Gaussian quadrature.
4. **Solutions of linear systems**: Gaussian elimination and backward substitution, pivoting strategies, LU decomposition method.

***Learning Outcomes*:**

1. Students will learn the definition of Floating point.
2. To gather knowledge about different types of Error.
3. Students will learn about Algorithm and Convergence.
4. Learn how to find roots of an equation by using different root findings method.
5. Apply various techniques' to solve the system of linear equations using various numerical methods.
6. Explain and understand how to use Newton's divided difference technique.
7. Could apply Spine quadrature and adaptive quadrature in some real life problems.
8. The readers will capture the knowledge of how to integrate numerically by using integral methods.
9. 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

MTH 207: Discrete Mathematics **Credits: 3**

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; recursive definitions; program verification.
2. **Combinatorics:** Counting principles; inclusion-exclusion principle; pigeonhole principle; generating functions; recurrence relations; applications to computer operations.
3. **Graph Theory:** Graphs; structure and symmetry of graphs; trees and connectivity; Eulerian and Hamiltonian graphs and diagraphs; directed graphs; planar graphs.
4. **Algorithms on graphs:** Introduction to graphs, paths and trees; shortest path problems: Dijkstra'a algorithm, Floyd-Warshall algorithm and their comparisons. Spanning tree problems: Kruskal's greedy algorithm, Prim's greedy algorithm and their comparison.

***Learning Outcomes*:**

1. ability to draw conclusions using given propositions by mathematical reasoning;
2. gather knowledge about basic counting principles;
3. generating and solving recurrence relations and applying those in practical problems;
4. understand various types and properties of graphs;
5. know how to use algorithms on graphs to solve some well-known problems;
6. identify the differences among graph, path and tree and know their properties.

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.
2. C. L Liu, Elements of Discrete Mathematics.
3. R. Kolman, R. C. Bushy, S. Ross, Discrete Mathematical Strictures.
4. R. P. Grimaldi and B. V. Ramana, Discrete and Combinatorial Mathematics: An Applied Introduction.

MTH 208: Programming Fundamentals **Credits: 3**

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.

***Learning Outcomes*:**

1. Acquire knowledge on Computer system and representation of data in computer.
2. Will learn basic structure of a program and to design a program.
3. History and basic elements of programming language FORTRAN.
4. Different control structures of FORTRAN and use of arrays.
5. Use of file and format in I/O.
6. Use of subroutine and to define functions.
7. Will be able to implement FORTRAN program in mathematical and scientific 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. Introduction to FORTRAN 90/95 for Scientists and Engineers by Stephen J. Chapman.
2. Modern FORTRAN Explained by Michael Metcalf, John Reid and Malcolm Cohen.
3. Introduction to Programming with FORTRAN by Ian Chivers and Jane Sleightholme.
4. Numerical Methods of Mathematics Implemented in FORTRAN by S.K. Bose.

MTH 250: Math Lab II (MATLAB)	**Credits: 3**
Problems in the courses of Second Year BS Honours will be solved using Computer Algebra System	

(CAS) **MATLAB**.

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

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

MTH 299: Viva Voce **Credits: 2**

Viva Voce on courses taught in the Second Year.

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List of Courses for Third Year (35 credits)

(Effective from 2020-2021 onwards)

MTH 301	Real Analysis II	3 credits
MTH 302	Complex Analysis	3 credits
MTH 303	Ordinary Differential Equations II	3 credits
MTH 304	Abstract Algebra	3 credits
MTH 305	Fundamentals of Topology	3 credits
MTH 306	Numerical Analysis II	3 credits
MTH 307	Mathematical Methods	3 credits
MTH 308	Optimization	3 credits
MTH 309	Stochastic calculus	3 credits
MTH 310	Introduction to Actuarial Mathematics	3 credits
MTH 350	Math Lab III (FORTRAN)	3 credits
MTH 399	Viva Voce	2 credits

MTH 301: Real Analysis II **Credits: 3**

Rationale:

This course is a continuation of elementary analysis of functions of single real variable to the elementary analysis of functions of several variables. To facilitate the analysis, required topological ideas of metric spaces. Their elementary properties and the basics of functions defined on a metric space are the objects of studies at the beginning of the course. The course provides the main background needed in modern Advanced Mathematics related to Real 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, we will study 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:** Uniform convergence. Interchangeability of limiting processes. Power series. Differentiation and integration of power series. Abel's continuity theorem.
2. **Metric Spaces:** Definition and examples. ε-neighborhood. Open and closed sets in metric spaces. Interior, exterior and boundary of a set. Bounded sets. Equivalent metrics. Cluster points of sets in metric spaces. Derive set. Closure of a set.
3. **Sequences in metric spaces:** Convergence. Cauchy sequences. Complete metric spaces.
4. **Continuity of functions:** Continuity and uniform continuity of functions on metric spaces.
5. **Compactness in metric spaces:** Necessary and sufficient condition for compactness. Heine-Borel theorem.
6. **Differentiation in R^n:** Definition and properties. Jacobian, implicit and inverse function theorems.
7. **Integration in R^n:**Definition and properties. Fubini's theorem.Change of variables.

Learning Outcomes

At the end of this course, students will have the knowledge of

1. Elementary topological properties of a metric space.
2. Success of infinite sequence and series of functions defined of a metric space.
3. Elementary analysis of functions of several variables. Limit, continuity, differentiability of a function, for example.
4. Applications of partial derivatives in optimization of a function.
5. Applications of inverse and implicit function theorem.
6. 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.

MTH 302: Complex Analysis Credits: 3

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.

Learning Outcomes:

1. Understand complex numbers and complex functions.
2. Understand the basic concepts of limit, continuity and differentiability of complex function
3. Understand the analytic function and Cauchy-Riemann equation
4. Understand the integration of complex functions and theorems related to complex integration
5. Solve some difficult integration using the theorems involving complex function
6. Understand the infinite series and singularities
7. 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.

MTH 303: Ordinary Differential Equations II **Credits: 3**

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 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.
2. **Series solutions of second order linear equations:** Taylor series solutions about an ordinary point. Frobenius series solutions about regular singular points.
3. **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.
4. **Bessel functions**: Generating function, recurrence relations, Bessel differential equation, Integral representations Orthogonality relations, Modified Bessel functions.
5. **Hermite & Laguerre polynomials:** Generating function, Rodrigue's formula, orthogonal properties, Hermite and Laguerre differential equation, recurrence relations, expansion theorems.
6. **Special functions:** Gamma function. Error function. Hyper geometric equation, special hyper

geometric function, Generalized hyper geometric function, special confluent hyperbolic functions.

7. **Systems of linear first order differential equations:** Elimination method. Matrix method for homogeneous linear systems with constant coefficients. Variation of parameters. Matrix exponential.

***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.

MTH 304: Abstract Algebra **Credits: 3**

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 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, and homological algebra.

***Course Objectives*:**

1. Introduce students to the basic concepts of algebraic structures embedded in Group and Ring Theories.
2. Explain to students the role commutativity plays in Abstract Algebra.
3. Demonstrate to students that there is a partial converse of Lagrange theorem.
4. Capture the canonical homomorphism via normality leading to isomorphism of two groups.
5. Demonstrate to students that this is a branch of pure mathematics whose 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. Demonstrate to students that there is a partial converse of Lagrange theorem.
9. Capture the canonical homomorphism via normality leading to isomorphism of two groups.
10. Upon completion of this course, students may take Advanced Abstract Algebra or Graph Theory with Applications.

Course Content:

Group A: Groups

1. Groupoids. Semigroups. Monoids. Order of an element of a group. Cyclic group.
2. 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 groups. Symmetric groups of permutations. Cyclic permutations. Transpositions. Even and odd permutations. Altering groups.
4. Homomorphisms and isomorphisms of groups. Cayley's theorem. Automorphism. Inner automorphism. Outer automorphism. The isomorphism theorems.

Group B: Rings

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

***Learning Outcomes*:**

Upon successful completion of this course, the student will be able to

1. 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.
2. State the Well-Ordering Principle of the positive integers and use it in a proof.
3. 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.
4. 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.
5. Construct a Cayley table for a group.
6. Demonstrate familiarity with the common groups.
7. Compute the order of a group, the order of a subgroup, and the order of an element.
8. Identify subgroups of a given group.
9. Identify cyclic groups and apply the fundamental theorem of cyclic groups.
10. Demonstrate familiarity with permutation groups and be able to decompose permutations into 2-cycles.
11. Define the concepts of homomorphism, isomorphism, and automorphism and check whether a given function defines one of these.
12. Prove the common properties of homomorphism.
13. Define the external direct product and be able to compute the direct product of groups.
14. Apply Lagrange's theorem.
15. Define normal subgroups and be able to prove that given subgroups are normal.
16. State and apply the fundamental theorem of finite Abelian groups.
17. Give a definition of ring and cite a variety of common examples and non-examples (finite and infinite, polynomials,and matrices).

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

References:

1. P.B. Bhattarcharya, S.K. Jain & S.R. Nagpaul, Basic Abstract Algebra.
2. W.K. Nicholson, Introduction to Abstract Algebra.
3. J.B. Fraleigh, Introduction to Abstract Algebra.
4. M. Artin, Algebra.
5. R S Aggarwal, A Text Book on Modern Algebra

MTH 305: Fundamentals of Topology **Credits: 3**

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
6. develop the student's ability to handle abstract ideas in topology to understand real world applications

Course Content:

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. **Continuous functions in topological spaces:** 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.

***Learning Outcomes*:**

Upon successful completion of this course, the student will be able to

1. distinguish among open and closed sets on different topological spaces;
2. identify precisely when a collection of subsets of a given set equipped with a topology forms a topological space;
3. construct maps between topological spaces to understand when two topological spaces are homeomorphic;
4. 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
5. determine that a given point in a topological space is either a limit point or not for a given subset of a topological space;
6. apply and use fixed point theorems to understand modern day applications
7. apply theoretical concepts in topology to understand real world applications.

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.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

MTH 306: Numerical Analysis II **Credits: 3**

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*:**

The objectives of this course are to

Course Content:

1. **Iterative Techniques in Matrix Algebra:**Jacobi method, Gauss-Seidel Method, SOR method, Eigenvalues and eigenvectors, the power method, Householder’s method, Q-R method.
2. **Nonlinear System of Equations:** Fixed point for functions of several variables, Newton’s method, Quasi-Newton’s method, Steepest Descent techniques.
3. **Initial value problems for ODE:** Euler’s and modified Euler’s method, Higher order Taylor’s method, Single-step methods (Runge-Kutta methods, extrapolation methods, higher order differential equations and systems of differential equations), Multi-step methods (Adams-

Bashforth, Adams-Moulton, Predictor-Corrector), error and stability analysis. Numerical solutions of Systems of Differential Equations (IVP)

4. **Boundary Value Problem for ODE:** Shooting method for linear and nonlinear problems, Finite difference methods for linear and nonlinear problems, the Rayleigh-Ritz Method (Piecewise Linear, and cubic splines).
5. **Finite Difference Method for PDEs:** Numerical Solution of initial boundary value problems (heat equation, one and two way wave equations in one space dimension only), 2D Elliptic BVPs using finite difference method.

***Learning Outcomes*:**

Upon successful completion of this course, the student will be able to

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.
5. L.W. Johson & R.D. Riess, Numerical Analysis.

MTH 307: Mathematical Methods **Credits: 3**

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 the finding of eigenvalues and eigenfunctions by solvingStrum-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. 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. Transforms of rational function. Convolution theorem. Parseval's theorem. 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.

***Learning Outcomes*:**

Students will be able to

1. Expand the periodic function of one variable by using Fourier series of real and complex forms.
2. Apply Fourier series expansion of periodic function of one variable to selected physical problems.
3. Understand the concept of Laplace transform and inverse Laplace transform of various function.
4. Solve initial value problems and boundary value problems using Laplace transform.
5. Calculate the Fourier transforms of simple functions and apply them to selected physical problems.
6. find the solution of the wave, heat flow and Laplace equations using the Fourier transforms
7. Solve integral equation.
8. Find the eigenvalues and the corresponding eigenfunctions by solving Strum-Liouvil boundary value problems.
9. Define the term "orthogonality" as applied to functions and recognize sets of orthogonal functions which are important in physics.
10. Find the Green's function from Strum-Liouvile boundary value problems.
11. 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** questions 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. W.N. Lebedev & R.A. Silverman, Special Functions and their Applications.
3. E. Kreuszig, Advanced Engineering Mathematics.
4. M. R. Spiegel, Laplace Transforms, Schaum's Outline Series.

MTH 308: Optimizations **Credits: 3**

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 formal science that uses methods like mathematical modeling, statistics, and algorithms to arrive at optimal or near optimalsolutions to real life problems and closely relates to IndustrialEngineering. 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 optimizationproblems in industries as diverse as banking, education, forestry, petroleum, and trucking.

***Course Objectives*:**

1. To give knowledge on mathematical formulations of real life problems.
2. Students will know different ways to solve the formulated mathematical models.
3. This course will help the students to learn the sensitivity analysis 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.

***Learning Outcomes*:**

Students will be able to

1. describe the basic properties such as convex sets and related theorems;
2. gather knowledge about LP, standard form, canonical form, slack variables, surplus variables, basic solutions, non-basic solutions, feasible solutions optimal solutions etc.;
3. know the ways to formulate a real life problem into a mathematical problem;
4. Solve 2-dimensional problems by using graphical method;
5. solve general LP problems by using simplex method (usual simplex method, 2-phase simplex method and Big-M simplex method);
6. solve special type of LP by Dual simplex method;
7. use sensitivity analysis to study the changes in availability, conditions etc.
8. solve NLP problems by different optimization methods
9. solve QP problems by different methods.

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.I. Gass, Linear Programming.
2. W. Winston, Operations Research.
3. G. Hadley, Linear Programming.
4. Ravindran, Phillips & Solberg, Operations Research.
5. Hiller and Liberman, Operations Research

MTH 309: Stochastic Calculus **Credits: 3**

Rationale:

First course in stochastic area; moving from distribution to stochastic process. Brownian motion and its properties have been discussed and how these properties characterize a stochastic process in Black and Scholes world have been considered. Crucial for students developing into Mathematical Finance, Actuarial Science and stochastic area of Mathematical Biology for further studies. Fundamental differences between classical calculus and stochastic calculus have been explored through Ito's formula. Firsthand stochastic differential equations have been studied with stock price modelling in view; filtration and sigma-algebra structures, and information flow in stochastic world, are introduced. Foundational course for research development in stochastic environment.

Course Contents:

1. Sigma algebra, filtration, conditional expectation and structure of stochastic process.
2. Martingale and Brownian motion stochastic process; construction of random walk, Brownian motion as a limit of random walk stochastic process. Distributional properties, correlation and covariance of Brownian motion stochastic process. First variation and quadratic variation of Brownian motion stochastic process. Simulation of Brownian motion paths. Martingale property of some useful Brownian motion functionals.
3. Ito's formula (with intuitive illustrations), stochastic integral and stochastic calculus.
4. Stochastic differential equations (SDE); details of basic SDE's; different numerical schemes (Euler, Milstein etc.) for simulating basic SDE's.
5. Calibrating parameters of some basic SDE's using real life (or simulated) data.

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. Lawrence C. Evans, An introduction to stochastic differential equations.
2. Ubbo F. Wiersema, Brownian motion Calculus.
3. Nigel Byott, Lectures on and illustrations of SDEs.

MTH 310: Introduction to Actuarial Mathematics **Credits: 3**

Rationale:

Actuaries are the back bone for the insurance company. Without them, there is no concept of 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, 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, Apportionable premiums.

Learning Outcome:

1. Compute different types of interests which is the most important learning for a business student.
2. Will calculate annuities and their application in life insurance.

3. Different types of risk model will give clear idea about the formulation of policy.
4. Learn how to use mortality tables to calculate commutation function.
5. 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** questions 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.

MTH 350: Math Lab III (FORTRAN) Credits: 3

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

MTH 399: Viva Voce Credits: 2

Viva Voce on courses taught in the Third Year.

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

List of Courses for FourthYear (35 credits)

(Effective from 2020-2021 onwards)

Common Courses: MTH 401 – MTH 406 (18 credits)

MTH 401	Introduction to Functional Analysis	Credit 3
MTH 402	Introduction to Measure Theory	Credit 3
MTH 403	Partial Differential Equations	Credit 3
MTH 404	Differential Geometry and Tensor Calculus	Credit 3
MTH 405	Mechanics	Credit 3
MTH 406	Hydrodynamics and Fluid Dynamics	Credit 3

Courses MTH 411 – MTH 420 to be offered by the Academic Committee
(Three courses has to be taken:9 credits)

MTH 411	Combinatorics	Credit 3
MTH 412	Fuzzy Mathematics	Credit 3
MTH 413	Population Dynamics	Credit 3
MTH 414	Scientific Computing and simulations	Credit 3
MTH 415	Introduction to Mathematical Finance	Credit 3
MTH 416	Stochastic Optimization	Credit 3
MTH 420	Special Topics	Credit 3
MTH 450	Math Lab IV	Credit 3
MTH 490	Honours Project	Credit 3
MTH 499	Viva-voce	Credit 2

MTH 401: Introduction to Functional Analysis **Credit: 3**

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. Familiaritywith 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.

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

MTH 402: Introduction to Measure Theory Credit: 3

Rationale:

This course is an introduction to measure and integration theory, and their applications to the approximation of real valued functions. The course focuses on the generalization of idea of length, area, and volume of a subset of Euclidean space to the so-called measure of a set. The idea of measure broadens the class of integrable functions compared to the Riemann integrable functions. Then we study convergence for sequences of integrable functions. The course is designed to provide the elementary introduction needed for an advanced abstract course on Measure and Integration.

Course Objectives:

The main objective of the course are generalization of idea of length, area, and volume of a subset of Euclidean space to measure of a set, exploiting the idea of measure to enrich the class of integrable functions from the class of Riemann integrable functions, and to discuss the properties of measurable functions and integration on $\mathbb{R}^{\mathbf{n}}$.

Learning Outcomes:

On completion of this course a student will learn the following basic ideas

1. Outer measure and measure as a generalization of volume of a set in Euclidian space.
2. Measurable functions and their properties, convergence sequence of measurable functions and its consequences.
3. Idea of measure helps to define integration of wider class of functions and its properties.
4. A student will get prepared for an advanced abstract course on measure and integration.

Course Content:

1. **Concepts of measure:** Sets and extended real number, Outer Measure and its properties, $\sigma-$algebra, Measures, Sets of measure zero, example of not measurable sets, and complete measure space.
2. **Lebesgue measures on $\mathbb{R}^{\mathbf{n}}$:**Lebesgue outer measure, Outer measures on rectangles. Caratheadory measurability, Null sets and completeness, Translational invariance of Lebesgue measure, Lebesgue measure under linear transformation, Borel sets, Borel regularity.
3. **Measurable functions:** Measurability of functions, Measurability of real (extended real) valued functions, Convergence in measure, pointwise convergence of sequence of measurable functions, Simple functions, Properties of functions that holds almost everywhere.
4. **Integrals:** Step functions, Simple functions, Positive functions, Lebesgue integrals of real valued functions and its properties, Comparison between Lebesgue and Riemann integrals.

Absolute continuity, Monotone convergence theorem. Limitations of Lebesgue integration, Lebesgue dominated convergence theorem, summation and integration.

5. **Differentiation and integration:** Differentiation of monotone functions, function of bounded variation, differentiation of an integral.

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

MTH 403: Partial Differential Equations — Credit: 3

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.

Learning Outcomes:

On completion of the course, the student will be able to:

1. describe the most common partial differential equations that appear in problems concerning e.g. heat conduction, flow, elasticity and wave propagation;
2. give an account of basic questions concerning the existence and uniqueness of solutions, and continuous dependence of initial and boundary data;

3. solve simple first order equations using the method of characteristics;classify second order equations;
4. solve simple initial and boundary value problems using e.g. d'Alembert's solution; formula, separation of variables, Fourier series expansion, Fourier transform methods;
5. describe, compute and analyse wave propagation and heat conduction in mathematical terms;
6. formulate maximum principles for various equations and derive consequences.

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.

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, FriesenPress.
4. **Nakhle H**. Asmar, Partial Differential Equations and Boundary Value Problems with Fourier Series,Dover Books on Mathematics.

MTH 404: Differential Geometry and Tensor Calculus **Credit: 3**

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.

Learning Outcomes:

Upon the successful completion of this course students will able to

1. Apply Serret-Frenet's Formulae to solve various types of problems.
2. Earn basic knowledge about tangent, normal, Binormal and different types of planes, Curvature, Torsion.
3. Solve to find tangent, normal, bi-normal and their lines, Curvature and Torsion of a space curve.
4. Gather knowledge about Spherical indicatrix of Tangent, Normal, Binormal, Curvature and Torsion.
5. Illustrate curves of involutes and evolutes and Bertrand curves.
6. Know how to find different types of fundamental forms of surfaces.
7. Know how to find the angle of two directions of surfaces.
8. Apply the concepts of fundamental magnitudes to find Mean Curvature and Gaussian Curvature.
9. Apply the concepts of tensor calculus to do various types of problem solution in Relativity, Cosmology and Geometry of Manifolds.
10. Apply the concepts of space curve to learn in future the spherical indicatrix of the tangent, tangent space and tangent bundle, smooth map and the knowledge of Manifolds in field of n-dimensional Geometry and theory of Relativity etc.

Course Content:

Group A: 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'sFormulae:** 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$f(x, y, z) = 0$. 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, DupinIndicatrix, Third Fundamental form, Theorem of Beltrami-Ennerper. The equation of Gauss-Weingarten.

Group B: Tensor Calculus

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

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.

MTH 405: Mechanics **Credit: 3**

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.

Learning Outcomes:

1. 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.
2. Further, general formulae for the determination of the centre of gravity and formulate for the centre of gravity by integration.
3. Definitions of stable and unstable equilibriums with examples.
4. 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.
5. Therefore, motion where the accelerations are parallel to fixed axes with tangential and normal accelerations.
6. Learning about apse, apsidal distance and apsidal angle and some important theorems related to the central force.
7. 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.

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

MTH 406: Hydrodynamics and Fluid Dynamics **Credit: 3**

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.

Learning Outcomes:

Upon completion of this course, students will explore the followings
1. To learn the basic knowledge on fluid properties (continuity, density, viscosity, and surface tension).
2. Describe the fundamental principles of the motion of ideal (inviscid) and real (viscous) fluid flows.
3. Apply analytical concepts to analyze a range of two-dimensional fluid flows, with appropriate choice of simplifying assumptions and boundary conditions.
4. To learn the dimensional analysis (basic/derived quantities, Buckingham's pi-theorem, similarity parameters).
5. To learn the fundamentals of fluid dynamics (different types of flows (steady/unsteady, viscous/inviscid, laminar), stream/path/streak lines), flowrate and hydrodynamic conservation laws (continuity equation, Euler's equation of motion, Bernoulli's theorem.
6. Investigate the physics/dynamics of a particular fluid flow giving a critical evaluation of the effect of significant flow and geometric parameters applying both hydrodynamic theory and knowledge from other disciples relevant to the problem.

Course Content:

GroupA: 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.

Group B: Fluid Dynamics

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

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 411: Combinatorics **Credit: 3**

Rationale:

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

Course Objectives:

The main objective of the course is for students to

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

Learning Outcomes:

Students will demonstrate the ability to:

1. Select and justify appropriate tools (induction, graphs, recurrences, complexity theory, generating functions, and probability) to analyze a counting problem.
2. Analyze a counting problem by proving an exact or approximate enumeration, or a method to compute one efficiently.
3. Describe solutions to iterated processes by relating recurrences to induction, generating functions, or combinatorial identities.
4. Understand, be able to prove and apply the fundamental results derived in the course, and solve unseen problems of similar kind; understand and be able to apply methods from elementary probability, analysis and linear algebra to a range of problems in discrete mathematics, including Ramsey theory.
5. Construct counting problems which show the usefulness or limitations of combinatorial tools.
6. Gain an appreciation of how methods from probability, analysis and algebra can be used to solve problems in discrete mathematics.

Course Content:

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

7. **Combinatorics in Different Faces**: Markov chain, The Stable Matching theorem, Arithmetic Combinatorics, Lovasz Local Lemma. Combinatorial games.

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

MTH 412: Fuzzy Mathematics **Credit: 3**

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 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, 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.

Learning Outcomes:

Students who successfully complete this course will:

1. Gather knowledge about fuzzy logic, fuzzy set theory and understand the difference between classical set and fuzzy set.
2. 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.
3. Gather knowledge about necessary and sufficient condition of a fuzzy set to be a fuzzy number.
4. Be able to do arithmetic operations of two fuzzy numbers and be also able to calculate their maximum and minimum.
5. Achieve knowledge of the concept of the procedure to get a solution of fuzzy equations.

6. Obtain the concept of binary fuzzy relation, domain, range, and inverse, composition of two binary fuzzy relations, some definitions, and theorems with proofs.
7. Achieve the idea of applications of fuzzy set theory and learn the methodology of using fuzzy sets in a real-life problem.

Course Content:

1. **Crisp Sets and Fuzzy Sets:** An overview of crisps sets; the notion of fuzzy sets; basicconcepts 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**.

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

MTH 413: Population Dynamics Credit: 3

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 point, periodic points, hyperbolic point and stability.

2. **Dynamics of one dimensional maps**: One parameter family of maps, contraction mapping, stability of fixed points and periodic points, family of logistic map, tent map, doubling map, linear maps, iterative map and quadratic family.
3. **Population Dynamics for Single Species**: Single species population model, growth 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 model, Lotka-Volterra model, competition model, cooperation model, war model and multi-species population 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, some infectious disease models (HIV/AIDS, TB model, etc), control of epidemic model.
7. **Optimal Control**: Basic Optimal control problems and necessary condition, existence and uniqueness of solution, principle of optimality.

Learning Outcomes:

By the end of this module, students

1. will know different basic dynamical tools by which a biological or physical system and its dynamics can be analyzed
2. will be able to develop simple models of biological phenomena based on basic principles
3. will be able to analyze the dynamics (briefly) of a biological system or a physical system
4. will be familiar with the mathematical modeling in Life sciences and different modeling techniques in different areas of Life sciences
5. will be familiar with basic emerging and re-emerging diseases and their basic dynamics
6. will explore the utility of using mathematical tools (of dynamical systems) to understand the properties and behaviors of biological systems

Evaluation:Incourse Assessment 30 Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of whichany **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 414: Scientific Computing and Simulations **Credits:3**

Rationale:

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

Course Objectives:

The main objectives of this course are to provide students
1. a rigorous description of the concepts of symbolic algorithms.
2. contemporary knowledge on some methods and techniques.
3. the knowledge of implementation of methods by using some software packages and toolkits.
4. introductory ideas about deterministic and stochastic simulations.

Course Content:

1. Introduction to symbolic mathematics systems. Effective use of symbolic mathematics systems and their limitations.
2. Exact versus approximate computation.
3. Key mathematical algorithms such as the Euclidean algorithm and the fast Fourier transform.
4. Integer and polynomial arithmetic. Solution of systems of polynomial equations (introduction to Groebner Bases). Applications of Groebner bases (digital signal processing, robotics).
5. Introduction to modular algorithms, their efficient implementation for fast symbolic/numeric computations.
6. Number theoretic algorithms in coding and cryptography.
7. Fast algorithms for multiplication of numbers and polynomials, for manipulation of series, fast matrix manipulation, fast factorization of polynomials.
8. Algorithmically solvable and unsolvable problems. Tarski-Seidenberg theorem. Mechanical theorem proving.
9. Modern algorithms for sorting, searching and retrieving information with applications to genomic research and text processing.
10. Quantifier elimination and applications to stability analysis and control theory.
11. Stochastic simulations: Monte Carlo method, Continuum simulations: Schrodinger equation in quantum mechanics.

Learning Outcomes:

After completing the course the students will be able to
1. master the main methods of non-numerical analysis of functions and processes
2. use the modern algorithms for searching information in targeted areas and the bases of algorithm construction and analysis
3. apply these methods to academic and simple practical instances
4. develop the abilities to design and conduct advanced numeric and symbolic experiments appropriate for an applied mathematical model, analyze and interpret their results.
5. apply various simulations in to solve practical problems in diverse fields.

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

MTH 415: Introduction to Mathematical Finance **Credit: 3**

Rationale:

Continuation of 3rd year module 'Stochastic Calculus' to the modern Mathematical Finance area. The domain of stochastic processes, mainly Brownian motion, in the application area of mathematical finance has been introduced with rigorous structural studies. Celebrated Black and Scholes model has been introduced, derived and intuitively explained which paves the path to study more advanced jump processes and ARCH/GARCH processes in mathematical finance area in MS.

Course Objectives &Learning Outcomes:

To get the stochastic mathematics concepts providing grounds to study the stock markets, bond markets and financial risk management used in banks and insurance companies; to engage in research and further studies in the horizon of Mathematical Finance, Actuarial Science and Financial Risk Management. Numerical simulation of studies of SDE's used in these areas are also in the objectives of this module.

Course Content:

1. **Brownian Motion (BM)**: Random Walk to BM; construction of BM; BM in stock price dynamics; covariance and correlation of BMN; slope, non-differentiability and measurement of variability of BM paths. Selected intuitive examples.
2. **Martingale**: Filtration, sigma-algebra, conditional expectation and martingale; properties of conditional expectation and martingale; examples of martingale analysis; revisiting BM as martingale.
3. **Ito Stochastic Integral and Ito Calculus:** Stochastic for non-random step functions and for non-anticipating general random integrands; properties of Ito Stochastic integrals; Stochastic differential equations and Ito integrals: functions of BM and frequently used Ito integrals for BM.
4. **Stochastic Differential Equations (SDE):** Structure of SDE; SDE for arithmetic BM; SDE for geometric BM; Ornstein-Uhlenbeck SDE; mean reversion SDE; square root SDE; Diffusion SDE. Introductory solutions of SDE.
5. **Option Valuation:** PDE method; Martingale method in one period binomial framework; martingale method in continuous time framework; valuation of European options like digital call, Asset-or-noting call, standard European call.

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

***References*:**

1. Ubbo F. Wiersema, Brownian motion Calculus, John Wiley and Sons
2. Steven E shreve, lecture notes:Stochastic Calculus for Finance-II.

MTH 416: Stochastic Optimization **Credit: 3**

Rationale:

The aim of stochastic programming (SP) is precisely to find an optimal decision in problems involving uncertain data. In this terminology, stochastic is opposed to deterministic and means that some data are random, whereas programming refers to the fact that various parts of the problem can be modeled as linear or nonlinear mathematical programs. The field, also known as optimization under uncertainty, is developing rapidly with contributions from many disciplines such as operations research, economics, mathematics, probability, and statistics.

Course Objectives:

The objective of this course is to provide a wide overview of stochastic programming. Introduction to Stochastic Programming is intended as a first course for beginning graduate students or advanced undergraduate students in such fields as operations research, industrial engineering, business administration and mathematics. This course provides worked examples of modeling a stochastic program. It introduces the basic concepts, without using any new or specific techniques. It describes how a stochastic model is formally built. It also stresses the fact that different models can be built, depending on the type of uncertainty and the time when decisions must be taken.

Course Content:

1. **Introduction**: Introduction to Stochastic Programming, basics of SP, formal approaches to stochastic programming, discussion of different problem classes and their characteristics, probability and random variables etc.
2. **Deterministic VS Stochastic Linear Program**: Linear Programming (LP) problems, LPs involving many variables when the outcome of the decisions can be predicted with uncertainty, uncertainty about the demand, uncertainty about the input prices**,** uncertainty about the technical coefficient matrix. LP equivalent of a SP.
3. **Two-Stage Recourse Problem:** Scenarios generation, formulation of scenario based SP, Formulation of 2-stage recourse problem, the solution in the 1st-stage, the solution in the second stage and application in real life. Fixed distribution pattern with fixed demand, fixed distribution pattern with uncertain demand, Variable distribution pattern with uncertain demand.
4. **Multi-Stage Recourse Problem:** Formulation of scenario based SP, Formulation of multi-stage recourse problem, solution in different methods and application in real life. . Fixed distribution pattern with fixed demand, fixed distribution pattern with uncertain demand, Variable distribution pattern with uncertain demand.
5. **Chance Constrained SP:** Formulation of chance constrained SP, solution in different methods and application in real life.
6. **Stochastic Integer Program:** Formulation of stochastic integer program (IP), recourse problems, simple integer recourse, probabilistic constraints, and solution in different methods and application in real life.

Learning Outcomes:

At the end of this course, students will be able to understand how the uncertainties involved in the decision making process are handled by using different methods of Stochastic Optimization. The students will be able to combine different areas of mathematics to produce new tools.
Students will be able to develop:

1. mathematical intuition and problem-solving capabilities;
2. understanding of which tool is appropriate to tackle uncertainties in problems;
3. ability to find information through tools like the world-wide web to solve problems;
4. ability to use computers to solve stochastic problems;
5. competency in mathematical presentation, and written and verbal skills.

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

References:

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

MTH 420: Special Topics **Credit: 3**

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

Evaluation: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.

MTH 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.

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

MTH 490: Honours Project **Credit: 3**

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

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

MTH 499: Viva Voce **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.

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

Implementation

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

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

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

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

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

Completion

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

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

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

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

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

Project Report	**50 marks.**
Project Presentation	**50 marks.**

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

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

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

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

Department of Mathematics

Four-Year BS Honours Programme

(Effective for 2020 -2021, 2021 - 2022)

List of Minor Courses for 1st Year BS (Honours)

Mathematics Minor Courses

For Honours Students of Departments other than Mathematics

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

First Year Minor

MTM 101	Fundamentals of Mathematics	2 credits
MTM 102	Calculus I	2 credits
MTM 103	Analytic and Vector Geometry	2 credits
MTM 104	Linear Algebra	2 credits
MTM 105	Calculus	4 credits

Detailed Syllabi

Course Code: MTM 101 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.

***Learning Outcomes*:**

After completion of this course Student will achieve the followings:

11. Learn to apply set theory on some physical problems;
12. Learn to identify the basic properties of the real number system;
13. Can solve elementary inequalities;
14. Can explain relations and functions and their relationship;
15. Know how to graph a function from its equation through its properties;
16. Identify the complex number system with some elementary properties.

17. Learn to find roots and their characteristics of polynomials
18. Able to obtain summation of a finite series.

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: MTM 102 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.

Learning Outcomes**:**

Students will be able to:

1. Calculate limits, derivatives, and indefinite integrals of various algebraic and trigonometric functions of a single variable.
2. Apply the definition of continuity to pure and applied mathematics problems.
3. Utilize the definition of the derivative to differentiate various algebraic and trigonometric functions of a single variable.
4. Use the properties of limits and the derivative to analyze graphs of various functions of a single variable including transcendental functions.
5. Employ the principles of the differential calculus to solve optimization problems, related rates exercises, and other applications.
6. Calculate the area of regions in the plane with elementary Riemann sums.
7. Utilize the Fundamental Theorem of Calculus and the techniques of integration, including u-substitution, to calculate the area of regions in the plane, the volume and surface area of solids of revolution and Arc length of curves.

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

Eight questions of equal value will be setof which **five** are to be answered, taking at least **two**questions from each group.

Text Books:

5. H. Anton, I. C. Bivens and S. Davis, **Calculus: Early Transcendentals**,Wiley.
6. E.W. Swokowski, **Calculus with Analytic Geometry**, Brooks/Cole.
7. G. B. Thomas and R. L. Finney, **Calculus and Analytic Geometry**, Addison Wesley.
8. J. Stewart, **Single Variable Calculus: Early Transcendentals**, Cengage Learning.
9. R. Larson, R. P. Hostetler, F. H. Edwards and D. E. Heyd, **Calculus with Analytic Geometry**, Houghton Mifflin College Div.

Course Code: MTM 103 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

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

***Learning Outcomes*:**

1. To solve problems involving lengths and distances in the plane.
2. Apply translations, rotations and orthogonal transformation of the coordinate axes to eliminate certain terms from equations.
3. Identify the homogeneous equation of 2^{nd} degree which represents pair of straight line or conics.
4. Sketch graphs of and discuss relevant features of curves including lines, circles, parabolas, ellipses, hyperbolas, and features such as slope, inclination, center, radius, vertices, foci, axes, eccentricity, intercepts, asymptotes.
5. Explain direction cosines and direction ratios, projection, distance of a point from a line and angle between two lines.
6. Illustrate different properties of plane and line in 3-space.
7. To understand the very basic about conicoids with sketches.

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: MTM 104 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^3 space. 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.

Learning Outcomes:

As a result of successfully completing this course, students should be able to demonstrate the following:

1. Analyze and interpret quantitative data verbally, graphically, symbolically and numerically.
2. Communicate quantitative data verbally, graphically, symbolically and numerically.
3. Appropriately integrate technology into mathematical processes.

4. Use mathematical concepts in problem-solving through integration of new material and modeling.

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:

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

Course Code: MTM 105 Credit: 4.0 Year: lst Type: Theory Course

Course Title: Calculus

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.
6. Understanding different form of integrals such as improper integral and its uses.

A. Differential Calculus

1. **Functions**: Functions and their graphs, polynomial and rational functions, logarithmic and exponential functions, trigonometric functions and their inverses, hyperbolic functions and their inverses, combination of functions.
2. **Limits of Functions**: Basic limit theorems with proofs, limit at infinity and infinite limits, continuous functions, algebra of continuous functions, extreme values and intermediate values of continuous functions on compact intervals (no proof required).
3. **Differentiation:** Tangent lines and rates of change, definition of derivative, one-sided derivatives, rules of differentiation (proofs and applications), successive differentiation, Leibnitz theorem (proof and application), related rates, linear approximations and differentials.
4. **Applications of the derivative**: Rolle's Theorem, Mean value theorem, Taylor's theorem, increasing and decreasing functions, extrema of functions, concavity and points of inflection, Optimization problems.

B. Integral Calculus

5. **Integrals:** Antiderivatives and indefinite integrals, definite integration using antiderivatives, definite integration using Riemann sums, fundamental theorem of calculus, basic properties of integration, integration by reduction.
6. **Applications of integration:** Plane areas, solids of revolution, volumes by cylindrical shells, volumes by cross-sections, arc length and surface of revolution. Graphing in polar coordinates, tangents to polar curves, areas in polar coordinates, arc length in polar coordinates.
7. **Improper integrals**: Gamma and Beta functions, indeterminate forms, L'Hospital's rules.
8. **Approximations and Series**: Taylor polynomials and series, convergence of series, Taylor's series, Taylor's theorem with remainder, differentiation and integration of series, validity of Taylor expansions and computations with series.

***Learning Outcomes*:**

Students will be able to:

1. Calculate limits, derivatives, and indefinite integrals of various algebraic and trigonometric functions of a single variable.
2. Apply the definition of continuity to pure and applied mathematics problems.
3. Utilize the definition of the derivative to differentiate various algebraic and trigonometric functions of a single variable.
4. Use the properties of limits and the derivative to analyze graphs of various functions of a single variable including transcendental functions.
5. Employ the principles of the differential calculus to solve optimization problems, related rates exercises, and other applications.
6. Calculate the area of regions in the plane with elementary Riemann sums.
7. Utilize the Fundamental Theorem of Calculus and the techniques of integration, including u-substitution, to calculate the area of regions in the plane, the volume and surface area of solids of revolution and Arc length of curves.
8. Gather ideas of gamma and beta function

9. Understand improper integration and uses of improper integration in probability distribution

Evaluation: Incourse Assessment: 30 marks. Final examination (Theory, 4 hours): 70 Marks. **Eight** questions of equal value will be setof 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.
4. J. Stewart, **Single Variable Calculus: Early Transcendentals**, Cengage Learning.
5. R. Larson, R. P. Hostetler, F. H. Edwards and D. E. Heyd, **Calculus with Analytic Geometry**, Houghton Mifflin College Div.

University of Dhaka

Department of Mathematics
Four Year B. S. Honours Programme

(Effective for 2020-2021, 2021-2022)

List of Minor Courses for 2nd Year BS (Honours)

Mathematics Minor 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

MTM 201	Mathematical Analysis	2 credits
MTM 202	Calculus II	2 credits
MTM 203	Ordinary Differential Equation	2 credits
MTM 204	Numerical Analysis	2 credits
MTM 205	Mathematical Methods	2 credits
MTM 206	Elementary Linear Algebra	2 credits

Detailed Syllabi

Course Code: MTM 201 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.

Learning Outcomes:

By the end of MTM 201: Mathematical Analysis, students should be able to:

1. Define and recognize the basic properties of the field of real numbers. Improve and outline the logical thinking.
2. Define and recognize the series of real numbers and convergence. Shown the ability of working independently and with groups.

3. Define and recognize Bolzano- Weirstrass theorem & ability to apply the theorem in a correct mathematical way.
4. Define and recognize the basic topological properties of R.
5. Define and recognize the real functions and its limits
6. Define and recognize the continuity of real functions
7. Define and recognize the differentiability of real functions and its related theorems
8. Define the real numbers, least upper bounds, and the triangle inequality.
9. Define functions between sets; equivalent sets; finite, countable and uncountable sets. Recognize convergent, divergent, bounded, Cauchy and monotone sequences.
10. Calculate the limit superior, limit inferior, and the limit of a sequence.
11. Recognize alternating, convergent, conditionally and absolutely convergent series.
12. Apply the ratio, root, limit and limit comparison tests.
13. Define metric and metric space.
14. Determine if subsets of a metric space are open, closed, connected, bounded, totally bounded and/or compact.
15. Determine if a function on a metric space is discontinuous, continuous, or uniformly continuous.
16. The Intermediate Value Theorem
17. Derivatives and the Mean Value Theorem
18. Sequences of Functions and Uniform Convergence
19. Power Series and Taylor Series
20. Riemann Integral

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: MTM 202 **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:

8. Fluency with vector operations and the various ways to describe vector valued functions.
9. 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.
10. A comprehensive understanding of the gradient, including its relationship to level curves (or surfaces), directional derivatives, and linear approximation.
11. 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.
13. 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.
14. The ability to set up and compute multiple integrals in rectangular, polar, cylindrical and spherical coordinates.
15. The ability to change variables in multiple integrals.
16. 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.

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: MTM 203 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

6. derive a basic first-order ODE model from a description of a physical system
7. understand the concepts of initial value problem and solution
8. 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
9. learn to solve differential equations with constant and variable coefficients
10. learn to solve real-world problems in fields such as Biology, Chemistry, Economics, Engineering, and Physics modeled by first and second order differential equations
11. gather experience to solve system of equations with constant coefficients.

Course Content:

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

8. **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.
9. **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.
10. **System of differential equations**, Linear system, Fundamental matrix. Solutions of linear systems with constant coefficient.

Learning Outcomes:

Upon completion of this course, the student should be able to

19. classify differential equations by order, linearity, and homogeneity
20. solve first order linear differential equations with and without initial conditions
21. determine regions of the plane over which a given first-order differential equation will have a unique solution
22. solve homogeneous linear equations with constant coefficients
23. use the method of undetermined coefficients and variation of parameters to solve differential equations
24. Construct a second solution of a differential equation from a known solution
25. use the method to solve differential equations with variable coefficients
26. 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 first order differential equations
27. system of equations with constant coefficients

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:

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

Course Code: MTM 204   Credit: 2.0   Year: 2nd   Type: Theory Course

Course Title: Numerical Analysis

Rationale:

Numerical analysis, area of mathematics and computer science that creates, analyzes, and implementsalgorithms for 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.

Learning Outcomes:

By the end of MTM 204: Numerical Analysis, students should be able to:

1. Find the root of an equation by using different methods.
2. Find the numerical integration by using different rules.
3. Perform numerical differentiation.
4. Find the solution of the initial value problem (IVP) by using different methods.
5. Investigate the solution of a system of linear equations by using different methods.
6. To design and analyze numerical techniques to approximate solutions to problems for which finding a closed-form (analytic) solution is not possible.
7. To learn about interpolation polynomials.
8. Demonstrate understanding of common numerical methods and how they are used to obtain approximate solutions to otherwise intractable mathematical
9. Apply numerical methods to obtain approximate solutions to mathematical problems.
10. Derive numerical methods for various mathematical operations and tasks, such as interpolation, the solution of linear and nonlinear equations, and the solution of differential equations.
11. 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 0-387-90420-4

Course Code: MTM 205 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.

Learning Outcomes:

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

1. Expand the periodic function of one variable by using Fourier series of real and complex forms.
2. Apply Fourier series expansion of periodic function of one variable to selected physical problems.

3. Understand the concept of Laplace transform and inverse Laplace transform of various function.
4. Solve initial value problems and boundary value problems using Laplace transform.
5. Calculate the Fourier transforms of simple functions and apply them to selected physical problems.
6. 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: MTM 206	**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.

Learning Outcomes:
After successfully completing MTH 206, students should be able to

13. Solve systems of linear equations and homogeneous systems of linear equations by Gaussian elimination and Gauss-Jordan elimination.
14. Row-reduce a matrix to either row-echelon or reduced row-echelon form.
15. Use matrix operations to solve systems of equations and be able to determine the nature of the solutions.
16. Understand some applications of systems of linear equations.
17. Perform operations with matrices and find the transpose and inverse of a matrix.
18. Calculate determinants using row operations, column operations and expansion down any column and across any row.
19. Interpret vectors in two and three-dimensional space both algebraically and geometrically.
20. Use the Gram-Schmidt process to produce an orthonormal basis.
21. Recognize the concepts of the terms span, linear independence, basis, and dimension, and apply these concepts to various vector spaces and subspaces,
22. Find the kernel, range, rank, and nullity of a linear transformation.
23. Calculate eigenvalues and their corresponding eigenspaces.
24. 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.
25. 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.

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.