Course Content for

3 Years B.Sc. Mathematics (Hons) Programme

School of Mathematical Sciences teaches 5 core courses per semester, each of 90 contact hours with 5 credit points. Apart from these, there are two enrichment courses of 15 contact hours each with 1 credit point per semester. The fifth & sixth Semester consists of projects from any of the topics listed at the end of this document.

Semester 1

Core Courses

Course 1: Elementary Calculus (Theory)

Pre-requisite	A reasonable knowledge on sets and functions and standard knowledge on limit, continuity, derivative and integration.
Objectives	This is considered to be one of the foundational courses for an undergraduate mathematics student. In this course, students first learn about two foundational concepts of mathematics and science, namely, limit of function and limit of sequence and understand how these concepts are useful to define two of the most applicable concepts called differentiation and integration. Then the students learn about differentiation and integration in broader details.
Outcomes	After completing this course, the students 1) Will gain significant understanding of limit, continuity, differentiability and a reasonable understanding of integrability. 2) Will be able to understand the applicability of these concepts.

Course 2: Elementary Calculus (Practicals)

Pre-requisite	Theoretical Knowledge Gained in Elementary Calculus (Theory) Course.
Objectives	The objective is to apply the theoretical knowledge gained in Elementary Calculus (Theory) course to understand monotonicity, concavity, convexity, linear approximation of non-linear function, existence and position of local extrema, rectilinear motion, and to calculate average value of function, length of plane curve, and volume of surface of revolution.
Outcomes	After completing this course, the students 1) Will know how the theoretical concepts and ideas taught in Elementary Calculus (Theory) course helped to answer some of the simple looking but very useful questions asked by not only mathematicians but also by Physicists, Scientists and many others.

Course 3: Elementary Number Theory (Theory)

Pre-requisite	Basic properties of integers, Integral exponents and powers
Course Description	This course on Number Theory involves numbers and their properties. Composite numbers, prime numbers and operations on numbers are vital to the foundation of mathematics and its applications. Number Theory involves purest of pure mathematics but we have structured the course not only to expose numbers but also to introduce its application in a modern field like Cryptography. We first develop the concept of linear congruence and related theories, which laid to the foundation of computer science. We then give a glimpse on its usefulness in introductory Cryptography. The last but not least important to mention that we focus on developing the quality of dealing with ideas rather than events.
Course Learning Objectives	1. Develop the basic mathematical theories related to divisibility of integers, prime and composite numbers, and linear congruence. 2. Understand the usefulness of this theory to introductory Cryptography.

Course 4: Elementary Number Theory (Practicals)

Pre-requisite	Theoretical knowledge of Elementary Number Theory
Course Description	This course emphasizes on solving problems using the theory developed in the theory course on Elementary Number Theory with applications in cryptography.
Course Learning Objectives	1. Apply the theories developed in Elementary Number Theory course to solve mathematical problems. 2. Encipher and decipher messages using cryptography.

Course 5: Linear Algebra (Theory)

Pre-requisite	Mathematics of Classes XI and XII (which include some basic knowledge of matrices).
Objectives	In this course, we study system of linear equations and Gaussian elimination method; vector space, bases and its dimension; linear transformations; inner product spaces and Gram-Schmidt orthogonalization; eigenvalue problems, triangularization, diagonalization and spectral theorem for normal matrices; and canonical forms of matrices. We end the course with a glimpse of linear programming problems.
Outcomes	1. Analyse and solve a system of linear equations 2. Important characteristics of matrices, such as its four fundamental subspaces, rank, determinant, eigenvalues and eigenvectors, different factorizations, etc.;

	3. How to use characteristics of a matrix to solve a linear system of equations or study properties of a linear transformation; 4. Important concepts of vector spaces such as independence, basis, dimensions, orthogonality, etc.;

Course 6: Linear Algebra (Practicals)

Pre-requisite	Theoretical knowledge of Linear Algebra
Course Description	This course emphasizes on solving problems using techniques developed in the theory course on Linear Algbera
Course Learning Objectives	**After successful completion of this course:** 1. **The students will able to analyze and solve problems involving systems of linear equations** **2. They should be able to solve problems on vector spaces, linear transformations and eigenvalues.** **3. They should be well acquainted with orthogonality and matrix factorizations.**

Course 7: Numerical Methods (Theory)

Pre-requisite	XI and XII Standard Mathematics
Course Description	This course emphasizes on several numerical techniques to get numerical solutions of many mathematical problems.
Course Learning Objectives	There are many scientific and engineering problems, such as finding roots of a transcendental equation, solutions of a system of linear equations, an area under a curve, solutions of differential equations, which often could not be treated analytically. Therefore, numerical studies are required for these cases. **After successful completion of this course:** 1. **The students will get a good knowledge of different numerical techniques.** 2. **They can study an approximate behaviour of any mathematical model for which exact behaviour is not known.**

Course 8: Numerical Methods (Practicals)

Pre-requisite	Theoretical knowledge of Numerical Methods
Course Description	This course emphasizes on solving problems using numerical techniques developed in the theory course on Numerical Methods.
Course Learning Objectives	**After successful completion of this course:** 1. **The students will able to solve problems using different numerical techniques.** **2. They will understand though several examples that these techniques may not always give the desired result in the sense that all these techniques requires certain hypothesis, which will be discussed in the theory course, to work properly.**

Course 9: Algorithms and Problem Solving Techniques (Theory)

Pre-requisite	Basics of computers and school level mathematics
Objectives	The course will train students in computer based problem solving technique and general approach of computer languages to getting computers to solve problems.
Outcomes	The students will (1) acquire competence in programming the computers 2) ability to evaluate efficacies of algorithms to solve various kinds of problems

Course 10: Algorithms and Problem Solving Techniques (Practicals)

Pre-requisite	Theoretical knowledge of Algorithms and Problem Solving Techniques
Objectives	The objective of the practical sessions is to get a hands on experience of utilizing the knowledge of algorithms and problem solving techniques learnt in the theory classes using computer programing languages
Outcomes	After completion of course, students will be able to: 1. Write programs in a compiled language such as C 2. Write programs in an interpreted language such as Python 3. Implement programs utilising fundamental algorithms, factoring, arrays, sorting and searching methods

Enrichment Courses

Apart from these, there are two short courses:

Course 11: People and personal management

This course involves discussions about how to manage your activities and time management as well as subtle points interacting with people. It also involves appreciating how people judge each other – the importance of first impressions and how to make them effective.

Course 12: Research writing and communication Skills

Communication is especially important to all of us. This may be in the form of oral communication or written communication. In order to achieve good communication, a backup work of research is also important. The course focuses on these issues.

Semester 2:

Core Courses

Course 1: Topology and Geometry (Theory)

Pre-requisite	Elementary Calculus and Real Analysis
Objectives	Gives a streamlined development of a course in Metric space topology, emphasizing the most useful concepts, familiarizing with concrete examples of spaces, and geometric ideas to encourage geometric thinking.
Outcomes	(1) To introduce the primitive concepts of open sets and introduce other concepts via that concept. (2) To discuss geometric motivations of concepts and results and lots of concrete and geometric examples and pictures.

Course 2: Topology and Geometry (Practicals)

Pre-requisite	Theoretical knowledge of Topology of Metric Spaces
Course Description	This course emphasizes on solving problems using techniques developed in the theory course on Topology of Metric Spaces
Course Learning Objectives	**After successful completion of this course:** **1. The students will able to analyze and solve problems involving open and closed sets, limit points, continuous functions and convergence.** **2. They should be well-versed with the notions of connectedness and compactness in metric spaces.** **3. They should be able to apply the several theorems learned in the course.**

Course 3: Real Analysis (Theory)

Pre-requisite	Elementary Calculus
Objectives	The properties of real numbers have been the guiding force in the development of advanced and abstract mathematics, which was proved to be one of the main ingredients in the development of modern scientific knowledge. Therefore, one should be pro-active to explore the real number system as early as possible. The present course is a complete development of these interesting properties and their usefulness.
Outcomes	After completing this subject, students will 1. Understand the important properties of real number systems. 2. Understand the usefulness of these properties in the advancement of mathematics.

Course 4: Real Analysis (Practicals)

Pre-requisite	Theoretical knowledge of Real Analysis
Objectives	This course emphasizes on solving problems using the theory developed in the theory course on Real Analysis with some mentions of real life applications.
Outcomes	After completing this course, students will 1) Understand the real number system better through examples. 2) Be able to apply the theory learnt in Real Analysis to solve Mathematical problems with some idea of real life applicability.

Course 5: Ordinary Differential Equations (Theory)

Pre-requisite	Elementary Calculus, Linear Algebra
Objectives	The objective of this course is to give an idea of differential equations and how to form a differential equation. Moreover, it will introduce various methods to get solutions of differential equations exactly.
Outcomes	After successful completion of this course: 1. The students will get a good knowledge different types of differential equations. 2. They can study an exact behaviour of any mathematical model which is reduced to ordinary differential equations.

Course 6: Ordinary Differential Equations (Practicals)

Pre-requisite	Theoretical knowledge of Ordinary differential equation
Objectives	The objective of this course is to give an idea of differential equations and how to form a differential equation. Moreover, it will introduce various methods to get solutions of differential equations exactly.
Outcomes	After successful completion of this course: 1. Students will be able to model differential equation 2. Students will be able to differentiate application of variety of technique taught. 3. Students will be able to find real life application.

Course 7: Elementary Probability (Theory)

Pre-requisite	Elementary Calculus
Objectives	Any realistic model of real world phenomenon must take into account the possibility of randomness. That is, more often than not, the quantities we are interested in will not be predictable in advance but, rather, will exhibit an inherent variation that should be taken into account by the model. This is usually accomplished by allowing the model to be probabilistic in nature. Such a model is, naturally enough, referred to as a probability model. In order to master both the "model building'' and the subsequent analysis of these models, one must have significant knowledge of basic probability theory. The present course is designed to give students a solid understanding of elementary probability.
Outcomes	After completing this course, students will 1) Understand the basic theory of probability and the meaning of probabilistic model. 2) Understand how to analyse probabilistic model using the basic theory of probability.

Course 8: Elementary Probability (Practicals)

Pre-requisite	Elementary Calculus and theoretical knowledge gained in Elementary Probability (Theory) course
Objectives	Any realistic model of real world phenomenon must take into account the possibility of randomness. That is, more often than not, the quantities we are interested in will not be predictable in advance but, rather, will exhibit an inherent variation that should be taken into account by the model. This is usually accomplished by allowing the model to be probabilistic in nature. Such a model is, naturally enough, referred to as a probability model. In order to master both the "model building'' and the subsequent analysis of these models, one must have significant knowledge of basic probability theory. The present course is designed to give students a solid understanding of the concepts in probability theory through explicit examples and calculations.
Outcomes	After completing this course, students will know how to calculate important numbers useful in analysing probabilistic and statistical model.

Course 9: Discrete Mathematics and Graph Theory (Theory)

Pre-requisite	Mathematics at 10+2 level, Elementary Number Theory
Objectives	This course will teach students how to reason and model combinatorically. The first part of the course is based on combinatorics. After a basic introduction to sets and functions, the students will be taught various counting principles, followed by theory of generating functions and subsequently methods to obtain solutions of various recurrence relations. Some special topics like Burnside's Theorem and Polya's Enumeration Formula will also be taught. The second part of the course is based on Graph Theory. After introducing graphs, basic properties of graphs and common types of graphs like bipartite, complete, regular, connected and planar graphs will be studied. The degree sum formula, Eulerian cycles and Hamiltonian circuits will be taught. Students will be introduced to graph coloring and lastly properties of trees, spanning trees and minimum spanning trees will be studied with applications.
Outcomes	After completion of course, students will be able to: 1. Understand and apply various counting principles 2. Able to compute different generating functions 3. Solve recurrence relations 4. Study and analyse various types of graphs and understand their properties 5. Understand the concepts of Eulerian cycle, Hamiltonian circuit and graph colouring 6. Analyse and study properties of trees, spanning trees in a graph and see applications.

Course 10: Discrete Mathematics and Graph Theory (Practicals)

Pre-requisite	Theoretical knowledge of Discrete Mathematics and Graph Theory
Objectives	• This course will teach students how to model combinatorically. The students will be taught problems on various counting principles and subsequently methods to obtain solutions of various recurrence relations. • Variety of problems will be solved after introducing graphs, basic properties of graphs and common types of graphs like bipartite, complete, regular, connected and planar graphs will be studied. The degree sum formula, Eulerian cycles and Hamiltonian circuits will be taught. Students will be introduced to graph colouring and lastly properties of trees, spanning trees and minimum spanning trees will be studied with applications.

Outcomes	After completion of course, students will be able to: 1. Understand and apply various counting principles 2. Able to compute different generating functions 3. Solve recurrence relations 4. To solve problems on Eulerian cycle, Hamiltonian circuit and graph colouring 5. Applications of properties of trees, spanning trees in a graph

Enrichment courses

Apart from these, there are two short courses:

Course 11: History of Indian mathematics

Mathematics began with numbers designed for keeping count of things. From there it went on to geometry and algebra and soon the field became a huge collection of ideas that evolved over several millennia. In this course, we will discuss how mathematics evolved.

Course 12: Environmental Sciences

Environment is under stress to an unprecedented scale. It is therefore important for young Students to become aware of the complexity of the issues related to environment

Semester 3:

Core Courses

Course 1: Theory of Optimization (Theory)

Pre-requisite	**Primary:** Linear Algebra **Secondary:** Elementary Calculus, Discrete Mathematics
Course Description	In this course, we study optimization problems, namely, Linear Programming Problem, Game Theory, Convex Programming Problem and Nonlinear Programming Problem. In Linear Programming Problem, we study the Simplex Method, Duality Theory, Transportation Problem, Network Flows, etc. In Game Theory, we study Two-Persons Zero Sum Game and Rectangular Game. In Convex Programming Problem, we study Optimization in Standard Form, Local and Global Optima, and an Optimality Criterion. In Nonlinear Programming Problem, we study Wolfe's Method and Beale's Method for quadratic programming problem, and Karush-Kuhn-Tucker Theory.
Course Learning Objectives	1. Analyse and solve Linear Programming Problems 2. Transportation Problems in Real Life 3. Network Flows 4. Two-Persons Zero Sum Game and Rectangular Game 5. Analyse and solve Convex Programming Problems 6. Analyse and solve Nonlinear Programming Problems

Course 2: Theory of Optimization (Practicals)

Pre-requisite	Theoretical knowledge of Theory of Optimization
Course Description	This course emphasizes on solving problems using the theory developed in the theory course on Theory of Optimization and modelling some simple real life problems to obtain the optimal solutions to them.
Course Learning Objectives	1. Model some simple real life problems where one or more quantities are required to be optimized under certain constraints. 2. Solve those problems to obtain the optimal solutions.

Course 3: Partial Differential Equations (Theory)

Pre-requisite	Elementary Calculus, Linear Algebra, Ordinary Differential Equation
Objectives	The objective of this course is to give an idea of differential equations and how to form a differential equation. Moreover, it will introduce various methods to get solutions of differential equations exactly.
Outcomes	After successful completion of this course: 1. The students will get a good knowledge different types of differential equations. 2. They can study an exact behaviour of any mathematical model which is reduced to ordinary differential equations.

Course 4: Partial Differential Equations (Practicals)

Pre-requisite	Theoretical knowledge of Partial differential equation
Objectives	The objective of this course is to give an idea of differential equations and how to form a differential equation. Moreover, it will introduce various methods to get solutions of differential equations exactly.
Outcomes	After successful completion of this course, students will be able to: 1. Model partial differential equations with given conditions. 2. Differentiate application of various techniques taught 3. Apply different techniques taught in real life problems.

Course 5: Multivariate Calculus (Theory)

Pre-requisite	Elementary Calculus and Real Analysis
Objectives	We first see different ways of representing functions of several variables. We introduce partial derivatives and use it to get various local information about the function such as tangent planes and directional derivatives. We will develop various techniques such as second derivative test and Lagrange multiplier methods to find local and global extrema of a multivariable function. Then we discuss some of the most important theorems including Boundedness Theorem, Extreme Value Theorem, Implicit Function Theorem, Inverse Function Theorem.
Outcomes	Many quantities in various scientific fields depend on more than one variable. After completing this course, the students will understand (i) How the concept of limit, continuity, differentiability and integrability is defined for such quantities. (ii) The mathematical techniques required to handle real world problems involving such quantities.

Course 6: Multivariate Calculus (Practicals)

Pre-requisite	Elementary Calculus, Real Analysis and Theoretical Knowledge Gained in Multivariate Calculus (Theory) Course.
Objectives	The objective is to discuss some of real life scenarios where multivariate functions occur frequently. Then to learn how to use partial derivatives to get various local information about the function such as tangent planes and directional derivatives. We then apply second derivative test and Lagrange multiplier methods to find local and global maxima and minima of multivariate function. We also discuss applications of some of the most important theorems including Boundedness Theorem, Extreme Value Theorem, Implicit Function Theorem, Inverse Function Theorem.
Outcomes	After completing this course this course, the students understand the techniques to tackle applications of multivariate function theory.

Course 7: Complex Analysis (Theory)

Pre-requisite	**Elementary Calculus, Real Analysis**
Objectives	We begin the course with properties of complex numbers. We study the differentiability and contour integration of complex valued functions in one complex variable. We further study zeros and poles of complex valued functions in one complex variable to evaluate contour integrations. We see applications of contour integration to evaluate definite real integrals.
Outcomes	After completing this course, the students will know 1. Properties of Complex Numbers 2. Differentiability of Complex Valued Functions in One Complex Variable 3. Contour Integration of Complex Valued Functions in One Complex Variable 4. Evaluation of Definite Real Integrals

Course 8: Complex Analysis (Practicals)

Pre-requisite	Elementary Calculus, Real Analysis and The Theoretical Knowledge Gained in Complex Analysis (Theory) Course.
Objectives	The objective is to learn complex differentiation and contour integration of complex valued functions in one complex variable, study zeros and poles of complex valued functions in one complex variable to understand how to evaluate contour integrations. Further, we see applications of contour integration to evaluate definite real integrals.
Outcomes	After completing this course, the students will know 1) Properties of Complex Numbers 2) Differentiability of Complex Valued Functions in One Complex Variable 3) Contour Integration of Complex Valued Functions in One Complex Variable 4) Evaluation of Definite Real Integrals

Course 9: Abstract Algebra (Theory)

Pre-requisite	(i) A reasonable knowledge on sets, relations and functions. (ii) Basic knowledge in elementary number theory.
Objectives	This is considered to be one of the foundational courses for an undergraduate mathematics student. The main concept of this course is to make students familiar to basic objects in abstract algebra like groups and rings. On one hand, while they will be introduced to the axioms of group theory and ring theory, on the other hand they will be taught to find appropriate models of the theory in various structures through plenty of examples. They will be introduced to some celebrated theorems and results in these fields and also will be taught to deduce interesting consequences of those results.
Outcomes	1. Understand the basic mathematical concepts in group theory and ring theory. 2. Understand how these concepts and ideas helped to answer some of the simple looking but very useful questions asked by not only mathematicians but also by Physicists, Scientists and many others. 3. Ability to write correct mathematical proofs.

Course 10: Abstract Algebra (Practicals)

Pre-requisite	Theoretical knowledge of Abstract Algebra
Course Description	This course emphasizes on solving problems using techniques developed in the theory course on Abstract Algebra
Course Learning Objectives	**After successful completion of this course:** **1. The students will able to solve problems using different results in abstract algebra.** **2. They will understand though several examples that there are many applications of these results in geometry and number theory.**

Enrichment courses:

Apart from these, there are two short courses:

Course 11: History of Mathematics in India.

Mathematics in India has a unique path and exploring the same provides a good insight into the very nature of Mathematics.

Course 12: Literature.
Literature written by Mathematicians such as Alice on Wonderland provide a fascinating insight into mathematics, literature and perspective of Mathematicians to the world

Semester 4:

Core Courses

Course 1: Vector Analysis (Theory)

Pre-requisite	Elementary Calculus, Linear Algebra, Multivariate Calculus
Objectives	• Students will learn to solve problems in three-dimensional space by utilizing vectors and vector-algebraic concepts. This includes representation in Cartesian, cylindrical and spherical coordinates. • We first see different ways of representing functions of several variables. Then we discuss line integrals, multiple integrals, and surface integrals, with applications to vector analysis.
Outcomes	After completion of this course, students will be able to: 1. Understand notion of a definite integral from a one-dimensional to an n-dimensional space, and be able to describe and evaluate double and triple integrals in Cartesian and curvilinear coordinates. 2. To work with vector-valued functions of several variables (i.e., vector fields) and be able to compute line and surface integrals. 3. To use the theorems of Green, Stokes, and Gauss to solve classical physics problems.

Course 2: Vector Analysis (Practicals)

Pre-requisite	Theoretical knowledge of Vector analysis
Objectives	• Students will learn to solve problems in three-dimensional space by utilizing vectors and vector-algebraic concepts. This includes representation in Cartesian, cylindrical and spherical coordinates. • We first see different ways of representing functions of several variables. Then we discuss line integrals, multiple integrals, and surface integrals, with applications to vector analysis.
Outcomes	After completion of course, students will be able to: 1. Evaluate double and triple integrals in Cartesian and curvilinear coordinates. 2. Compute line and surface integrals. 3. To use the theorems of Green, Stokes, and Gauss to solve classical physics problems and find its real life application.

Course 3: Topology and Geometry (Theory)

Pre-requisite	Linear Algebra, Multivariable Calculus, Real Analysis, Ordinary Differential Equations, Topology of Metric Spaces
Objectives	In this course, differential geometry will be taught. Firstly, the theory of curves will be introduced through the concepts of coordinates, arclength and curvature. Secondly, surfaces will be studied. The Gaussian curvature, an analog of curvature of curves for surfaces, will be introduced. Students will also be taught the concepts of tangent plane and unit normal. It will be shown that Gaussian curvature is an intrinsic feature of a surface. The concept of vector fields and parallel transport will be introduced. Students will be taught geodesics. They will be made familiar with important results like the Hopf-Rinow Theorem and Hopf's Umlaufsatz. Finally, Gauss-Bonnet theorem will be proved and some applications will be given. After the part in differential geometry has been completed, students will be taught some basic topics in algebraic topology like homotopic maps and the fundamental group. Fundamental group of the real circle will be computed. The students will be introduced to the Van Kampen's Theorem (proof to be done if time permits) and some applications will be given.
Outcomes	1. Analyse and study curves and surfaces through measures of curvature, arc-length etc. 2. To be able to compute tangent plane and unit normal 3. Understand the concepts of coordinate charts, differentiable maps between surfaces. 4. Analyse and study different curvatures of surfaces. 5. Understand the concept of geodesics 6. Understand the concept of homotopy and the fundamental group. 7. Study applications of the results learned.

Course 4: Topology and Geometry (Practicals)

Pre-requisite	Theoretical knowledge of Topology and Geometry
Course Description	This course emphasizes on solving problems using techniques developed in the theory course on Topology and Geometry
Course Learning Objectives	**After successful completion of this course:** 1. **The students will able to solve problems on different curves and surfaces.** **2. They should learn some major applications of some important theorems of geometry.** **3. They should be comfortable in using various techniques of algebraic topology in solving problems on geometry**

Course 5: Statistics and Machine Learning (Theory)

Pre-requisite	Probability concepts, Basic programming
Objectives	By the end of the course, students should be able to (i) develop an appreciation for what is involved in learning models from data, (ii) understand a wide variety of statistical learning algorithms and evaluation of models generated from data, and (ii) apply the algorithms to a real-world problem.
Outcomes	(i) Understanding and implementation of statistical machine learning algorithms. (ii) Utilisation of neural networks for regression of numerical data and classification of images.

Course 6: Statistics and Machine Learning (Practicals)

Pre-requisite	Theoretical knowledge of Statistics and Machine Learning
Objectives	The objective of the practical sessions is to get hands-on experience of implementing systems using statistical and machine learning techniques, learnt in theory classes, using a computer programming language.
Outcomes	The students will be able to implement and analyse 1. Linear and logistic regression models 2. Dimensionality reduction using principal component analysis 3. Regression and classification using neural networks

Course 7: Measure Theory (Theory)

Pre-requisite	Real Analysis and Elementary Probability
Objectives	Measure Theory formalises and generalises the notion of integration. It is fundamental to many areas of mathematics and probability and has applications in other fields such as physics and economics. This is a course without which the knowledge of probability theory is impossible to apply in modern day real life problems, for instance, stock market. A lot of seemingly elementary applications of probability theory will be better understood if viewed through the eyes of somebody who studied measure theory.
Outcomes	After completing this course, 1. Students will understand the fundamentals of Lebesgue theory. 2. They will be acquainted with the proofs of the fundamental theorems underlying the theory of integration.

	3. They will get a glimpse on how abstract theory of measure and integration is developed as generalized Lebesgue theory. 4. They will learn about one of the most important function spaces namely, L^p-spaces.

Course 8: Measure Theory (Practicals)

Pre-requisite	Real Analysis, Elementary Probability and Theoretical Knowledge Gained in Measure Theory (Theory) course.
Objectives	Measure Theory formalises and generalises the notion of integration. It is fundamental to many areas of mathematics and probability and has applications in other fields such as physics and economics. This is a course without which the knowledge of probability theory is impossible to apply in modern day real life problems, for instance, stock market. A lot of seemingly elementary applications of probability theory will be better understood if viewed through the eyes of somebody who studied measure theory.
Outcomes	After completing this subject, 1) Students will understand the fundamentals of Lebesgue theory. 2) They will be acquainted with the proofs of the fundamental theorems underlying the theory of integration. 3) They will get a glimpse on how abstract theory of measure and integration is developed as generalized Lebesgue theory. 4) They will learn about one of the most important function spaces namely, L^p-spaces.

Course 9: Functional Analysis (Theory)

Pre-requisite	Linear Algebra, Real Analysis
Objectives	We begin the course with Linear Spaces and Linear Maps. We study Metric Spaces and Continuous Functions. We study Banach Spaces with an emphasis on L^p Spaces. We study Bounded Linear Maps on Banach Spaces and the Spectrum of Bounded Operators on Banach Spaces. We further study Hilbert Spaces and Bounded Operators on Hilbert Spaces.
Outcomes	After Completing this Course Successfully, Students will Understand 1. Banach Spaces 2. Bounded Operators and their Spectrum on Banach Spaces 3. Hilbert Spaces 4. Bounded Operators on Hilbert Spaces

Course 10: Functional Analysis (Practicals)

Prerequisite	Theoretical knowledge of Functional Analysis
Objectives	This course emphasizes on solving problems using the theory developed in the theory course on Functional Analysis with some mentions of applications in Physics.
Outcomes	After Completing this Course Successfully, Students will 1. Have plenty of Examples of Banach Spaces and Hilbert Spaces some of which are used in Physics 2. Be able to Calculate the Operator Norm on Banach Spaces 3. Be able to find Spectrum of Bounded Operators on Banach Spaces 4. Understand the behaviour of Bounded Operators on Hilbert Spaces

Enrichment courses

Apart from this, there are two short courses:

Course 11: Microeconomics. Microeconomics heavily involves mathematical ideas and concepts. The course explores basic concepts of microeconomics and its mathematical ideas.

Course 12: Presentation Techniques. These techniques are crucial to students as they move out of their comfort zone of classroom and move into real world where they need to present their work and plan in a manner which is effective in front of unknown audiences. The course highlights these issues.

Semester 5:

Core Courses

Course 1: Coding Theory (Theory)

Pre-requisite	Elementary Number Theory, Discrete Mathematics and Graph Theory, Linear Algebra, Abstract Algebra
Course Description	The object of this course is to present the fundamentals of the subject of Coding Theory. We will start with the definition of a block code and of distance between words of equal length. Using the maximum likelihood decoding procedure, we obtain necessary and sufficient conditions for a code to (i) detect, (ii) correct any set of k or fewer errors. Matrix codes and polynomial codes will be studied along with generators and parity check matrices. Single error correcting codes like Hamming codes will be studied in detail along with BCH codes, which are polynomial. Linear codes and dual of linear codes will be studied. Cyclic codes will be introduced and it will be shown that BCH and Hamming codes are cyclic codes. Also quadratic residue codes and MDS codes will be studied. Finally the course will end with some selected topics like RSA cryptosystem, Huffman codes and automorphism of codes.
Course Learning Objectives	1. Understand the concepts of Error Correcting Codes 2. Study various types of codes, like group codes, polynomial codes, matrix codes, Hamming codes, BCH codes etc. 3. Understand the algebraic concepts involved with these codes.

Course 2: Coding Theory (Practicals)

Pre-requisite	Elementary Number Theory, Discrete Mathematics and Graph Theory, Linear Algebra, Abstract Algebra
Course Description	The object of this course is to present the fundamentals of the subject of Coding Theory. We will start with the definition of a block code and of distance between words of equal length. Using the maximum likelihood decoding procedure, we obtain necessary and sufficient conditions for a code to (i) detect, (ii) correct any set of k or fewer errors. Matrix codes and polynomial codes will be studied along with generators and parity check matrices. Single error correcting codes like Hamming codes will be studied in detail along with BCH codes, which are polynomial. Linear codes and dual of linear codes will be studied. Cyclic codes will be introduced and it will be shown that BCH and Hamming codes are cyclic codes. Also quadratic residue codes and MDS codes will be studied. Finally the course will end with some selected topics like RSA cryptosystem, Huffman codes and automorphism of codes.

Course Learning Objectives	**1. The students will able to analyze and solve problems involving** Error Correcting Codes **2.** They should be able to solve problems on various types of codes, like group codes, polynomial codes, matrix codes, Hamming codes, BCH codes etc. **3.** Understand and apply the algebraic concepts involved with these codes.

Course 3: Fourier and Wavelet Analysis (Theory)

Pre-requisite	Real Analysis, Linear Algebra, Numerical Analysis
Objectives	• The objective of this course is to present some of the recent advances in Fourier and Wavelets analysis. The course starts with the classical ideas of Fourier series and the Fourier transform and progresses to the construction of Wavelets. • This course includes Fourier analysis at the undergraduate level develop the tools on Fourier analysis and then apply these tools to the solution of ordinary and partial differential equations. • The discussion of Fourier analysis serves the purpose of construction of wavelets using the tools from Fourier analysis. • Wavelets provide the time localization that is not part of standard Fourier series and this time localization is presented as the motivation for looking at wavelets.
Outcomes	After completion of course: 1. The course gives basic mathematical understanding of fundamental subjects, which has applications in the development of tools, and techniques, which may be used in signal theory, communication techniques, graphical algorithms and numerical analysis. 2. The course is also an entrance to various concrete aspects of functional analysis, which has interest for other parts of mathematics.

Course 4: Fourier and Wavelet Analysis (Practicals)

Pre-requisite	Theoretical knowledge of Fourier and Wavelet Analysis
Objectives	• The objective of this course is to present some of the recent advances in Fourier and Wavelets analysis. The course starts with the classical ideas of Fourier series and the Fourier transform and progresses to the construction of Wavelets. • This course includes Fourier analysis at the undergraduate level develop the tools on Fourier analysis and then apply these tools to the solution of ordinary and partial differential equations.

	• The discussion of Fourier analysis serves the purpose of construction of wavelets using the tools from Fourier analysis. • Wavelets provide the time localization that is not part of standard Fourier series and this time localization is presented as the motivation for looking at wavelets.
Outcomes	After completion of this course, students will be able to: 1. Understand mathematical calculation of Fourier and Wavelet transformation. 2. Find applications in the development of tools, and techniques, which may be used in signal theory, communication techniques, graphical algorithms and numerical analysis.

Course 5: Sequence: Statistical and Deep Learning Approaches (Theory)

Pre-requisite	Probability, exposure to Machine Learning and Python programming
Objectives	The main objective is to analyze and model sequences, including time-series. This involves (i) modeling and forecasting of stationary and non-stationary time series using statistical methods, (ii) modeling quasi-stationary sequences using probabilistic models such as hidden Markov model and Gaussian Mixture model, and (iii) modeling sequences using Deep Learning techniques.
Outcomes	(i) Understand and implement statistical models for time-series. (ii) Learn and implement models for recognition of sequential patterns using probabilistic and deep learning approaches. (iii) Exposure to applying these techniques to problems in areas such as time-series, speech, text, bioinformatics.

Course 6: Sequence: Statistical and Deep Learning Approaches (Practicals)

Pre-requisite	Probability, exposure to Machine Learning and Python programming
Objectives	The main objective is to analyze and model sequences, including time-series. This involves (i) modeling and forecasting of stationary and non-stationary time series using statistical methods, (ii) modeling quasi-stationary sequences using probabilistic models such as hidden Markov model and Gaussian Mixture model, and (iii) modeling sequences using Deep Learning techniques.
Outcomes	(i) Understand and implement statistical models for time-series. (ii) Learn and implement models for recognition of sequential patterns using probabilistic and deep learning approaches. (iii) Exposure to applying these techniques to problems in areas such as time-series, speech, text, bioinformatics.

Course 7: Project Exploration

Semester 6:

Core Courses:

Course 1: Analytic Number Theory (Theory)

Pre-requisite	Elementary Number Theory, Complex Analysis
Course Learning Objectives	Carl Friedrich Gauss, one of the greatest mathematicians, is said to have claimed "Mathematics is the queen of the sciences and number theory is the queen of mathematics". The properties of prime numbers play a crucial part in number theory. This course is an introduction to analytic number theory, leading to the use of zeta function and L-functions to prove distribution results concerning prime numbers.
Outcomes	After completing this course, the students will know 1) about arithmetic functions, Dirichlet multiplication, multiplicative functions, averages of arithmetic functions, characters of finite abelian groups 2) their use to describe and explain some elementary theorems on the distribution of primes and Dirichlet's theorem on primes in arithmetic progressions.

Course 2: Analytic Number Theory (Practicals)

Pre-requisite	Elementary Number Theory, Complex Analysis and Theoretical Knowledge Gained in Analytic Number Theory (Theory) Course.
Course Learning Objectives	Carl Friedrich Gauss, one of the greatest mathematicians, is said to have claimed "Mathematics is the queen of the sciences and number theory is the queen of mathematics". The properties of prime numbers play a crucial part in number theory. This course is an introduction to analytic number theory, leading to the use of zeta function and L-functions to prove distribution results concerning prime numbers.
Outcomes	After completing this course, the students will know 1) about arithmetic functions, Dirichlet multiplication, multiplicative functions, averages of arithmetic functions, characters of finite abelian groups 2) their use to describe and explain some elementary theorems on the distribution of primes and Dirichlet's theorem on primes in arithmetic progressions.

Course 3: Applied Linear Algebra (Theory)

Pre-requisite	Elementary Calculus, Linear Algebra, Abstract Algebra, Differential equation
Objectives	• A general aim with the course is that the student should developa good understanding of basic mathematical concepts within algebra and geometry and be able to use these to mathematical modelling of engineering and scientific problems. • The student should develop skills in, using computers, illustrating central concepts and solving applied problems by means of functions from the library of the programming language. Furthermore, the student should be able to visualise and present the results in a clear way.
Outcomes	Use computational techniques and algebraic skills essentialfor the study of systems of linear equations, matrix algebra,vector spaces, eigenvalues and eigenvectors, orthogonality and diagonalization. Use of algebraic and operator techniques to solve engineeringand scientific problems.

Course 4: Applied Linear Algebra (Practical)

Pre-requisite	Elementary Calculus, Linear Algebra, Abstract Algebra, Differential equation
Objectives	• A general aim with the course is that the student should develop a good understanding of basic mathematical concepts within algebra and geometry and be able to use these to mathematical modelling of engineering and scientific problems. • The student should develop skills in, using computers, illustrating central concepts and solving applied problems by means of functions from the library of the programming language. Furthermore, the student should be able to visualise and present the results in a clear way.
Outcomes	Use computational techniques and algebraic skills essential for the study of systems of linear equations, matrix algebra, vector spaces, eigenvalues and eigenvectors, orthogonality and diagonalization. Use of algebraic and operator techniques to solve engineering and scientific problems.

Course 5: Final Project with open Defence

Students are expected to do project on any of the topic listed below:

(1) Fine and Performing Arts
(2) Social Organisation
(3) Social Dynamics
(4) Statistical Studies
(5) Business Analytics
(6) Management
(7) Computer Science
(8) Data Science
(9) Simulations and Animations
(10) Engineering
(11) Industrial Mathematics
(12) Physical Sciences
(13) Biomathematics
(14) Earth Sciences
(15) Mathematics
(16) Education
(17) Any Other Topic of Human Learning