RAMAKRISHNA MISSION VIVEKANANDA CENTENARY COLLEGE

RAHARA, KOLKATA-700118

DEPARTMENT OF MATHEMATICS

SESSION 2017-18

Programme Outcomes, Programme Specific Outcomes, Course Objectives and Course Outcomes of UG Syllabus for B.Sc. Mathematics

Principal
Ramakrishna Mission
Vivekananda Centenary College
Rahara, Kolkata-700 118

PROGRAM OUTCOMES

After completion of the B.Sc. Degree program, the students will be able to

PO No.	Program Outcomes	Cognitive Level
PO 1	Recognize the scientific tempers and attitudes, which in turn can prove to be beneficial for the society since the scientific developments can make a nation or society to grow at a rapid pace.	R
PO 2	Understand scientific knowledge and exchange ideas with other stakeholders; make people aware about sustainable utilization of resources with ethical approach.	U
PO 3	Understand and apply the issues of environmental contexts and sustainable development as a basic interdisciplinary concern.	U, Ap
PO 4	Create the ability to perform experiments and to analyse & interpret the obtained accurate results and thus gain the ability to solve problems, to involve in critical, independent, and creative thinking.	An, E, C
PO 5	Possess expertise to apply and formulate ideas which will provide them competitive advantage in pursuing higher studies from India or abroad; and seek jobs in academia, research or industries.	Ap, E
PO 6	Assemble the acquired in-depth knowledge of applied subjects towards the inculcation of professional and employment skills so that students can make a career and become an entrepreneur in diverse fields.	C

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PROGRAMME SPECIFIC OUTCOMES

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

PSO No.	Program Specific Outcomes	Cognitive Level
PSO1	Explain the core ideas and the techniques of mathematics at the college level and recognize the power of abstraction and generalization, and to carry out investigative mathematical work with independent judgment.	R, U
PSO2	Set up mathematical models of real-world problems, obtain solutions in structured and analytical approaches, carry out objective analysis and prediction of quantitative information with independent judgment.	Ap
PSO3	Learn numerical aptitude applying both qualitative and quantitative knowledge for their future career and being a responsible citizen towards their community and a sustainable environment.	Ap, E
PSO4	Communicate to lay audiences and arouse their interest in the beauty and precision of mathematical arguments and science and recognize the importance of compliance with the ethics of science.	An, C
PSO5	Collaborate effectively in team work and team building, conduct self-evaluation, and continuously enrich themselves through lifelong learning.	C

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Course Structure: Semester-wise distribution of Courses

Honours

Semester -I		
Course Code	Title	Credits
UGAECC-I	English Communication	2
UGMATHCC01	Calculus, Geometry & Differential Equation & Practical	4+2
UGMATHCC02	Algebra & Tutorial	5+1
Semester-II		
UGAECC-II	Environmental Science (Envs)	2
UGMATHCC03	Real Analysis & Practical	4+2
UGMATHCC04	Differential Equations & Vector Calculus & Practical	5+1
Semester -III		
UGMATHCC05	Theory of Real Functions & Introduction to Metric Spaces	65+1
UGMATHCC06	Group Theory I & Tutorial	5+1
UGMATHCC07	Numerical Methods & Practical - Numerical Methods Lab	4 +2
Semester -IV		
UGMATHCC08	Riemann Integration and Series of Functions	5+1
UGMATHCC09	Multivariate Calculus	5+1
UGMATHCC10	Ring Theory and Linear Algebra I	5+1
Semester -V		
UGMATHCC11	Partial Differential Equations and Applications & Practical	4+2
UGMATHCC12	Group Theory II & Tutorial	5+1
Electives		
UGMATHDSE1	Linear Programming & Tutorial	5+1
UGMATHDSE2	Probability and Statistics & Tutorial	5+1
Semester -VI		
UGMATHCC13	Metric Spaces and Complex Analysis & Tutorial	5+1
UGMATHCC14	Ring Theory and Linear Algebra II & Tutorial	5+1
Electives Choose any two of the following courses		
UGMATHDSE3 UGMATHDSE4	1.Mechanics & Tutorial	5+1
	2.Bio Mathematics & Practical	4+2
	3.Point Set Topology & Tutorial	5+1
Skill Enhancement Subjects		
UGMATHSEC1	Logic and Sets	2
UGMATHSEC2	Python 3.4.3	2
Generic Elective Subjects Syllabus		
UGMATHGE01	Algebra & Tutorial	5+1
UGMATHGE02	Calculus, Geometry and Differential Equation & Tutorial	5+1
UGMATHGE03	Numerical Methods & Tutorial	5+1
UGMATHGE04	Group Theory & Tutorial	5+1
GRAND TOTAL		**140**

SEMESTER – I
Name of the Course: **English Communication**
Course Code: **UGMATHAECC-I**

Course Objectives (UGMATHAECC-I)

The prime objectives of the course are:

- In-depth knowledge of language skills – Listening, Speaking, Reading and Writing.
- In-depth knowledge of grammar and their applications in Speaking, Reading and Writing Skills.
- To provide expertise and consultancy services in the private and public sector and to be an entrepreneur/professional consultant.
- To opt for higher education, research and to be a life-long learner.
- To provide value based and ethical leadership to the profession and social life.

Course Outcome (UGMATHAECC-I)

By the end of the program, the students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Engage in self-directed English language learning.	R,	PO1, PO2, PO3	PSO 1
CO 2	Be responsible and ethical English users.	R, U	PO1, PO2, PO3	PSO 1
CO 3	Enhance their English language proficiency in the aspects of reading, writing, listening and speaking.	R, U	PO1, PO2, PO3	PSO 1
CO 4	Develop academic literacy required for undergraduate learning, further studies and research.	Ap	PO3, PO5	PSO 2
CO 5	Apply the requisite communicative skills and strategies to future careers.	Ap,	PO3, PO5	PSO 2
CO 6	Gain an insight into cultural literacy and cross-cultural awareness.	Ap	PO3, PO5	PSO 2

SEMESTER – I
Name of the Course: **Calculus, Geometry & Differential Equation**
Course Code: **UGMATHCC01**

Course Objectives (UGMATHCC01)

The prime objectives of the course are:

- To introduce the students to the exciting world of differential equations, mathematical modelling and their applications.

- To evaluate integration of irrational functions and improper integrals.
- To understand the concepts of double and triple integration.
- Calculate definite integrals that may involve logarithms, exponentials, polynomials, and powers by using the Fundamental Theorem of Calculus.

Course Outcomes (UGMATHCC01)

After completing the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSO Addressed
CO1	Recall the basic concepts of conics and classification of quadrics.	U, R	PO1, PO2, PO3	PSO1
CO2	Construct a variety of differential equations analytically and numerically.	Ap	PO3, PO5	PSO2
CO3	Measure/calculate length, perimeter, area, volume of surface of revolution of a curve and techniques of sketching conics.	Ap, E	PO3, PO4, PO5	PSO3
CO4	Develop ability to graphically analyze functions by computer practical.	C	PO4, PO6	PSO5

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SEMESTER – I
Name of the Course: **Algebra**
Course Code: **UGMATHCC02**

Course Objectives (UGMATHCC02)

The prime objectives of the course are:

- To introduce the basic tools of theory of equations, complex numbers, number theory and matrices.
- To understand the connection of algebra with the real-world problems.
- Perform matrix algebra with applications to computer graphics.
- Learn to solve systems of linear equations and application problems requiring them.

Course Outcomes (UGMATHCC02)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understand complex numbers, way of representing numbers, relationships among numbers, different method for solving polynomial equations.	Ap	PO3, PO5	PSO2
CO2	Solve linear equations.	Ap	PO3, PO5	PSO2
CO3	Demonstrate their ability to graphically or numerically analyze functions by presentation.	C	PO4, PO6	PSO5

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SEMESTER – II
Name of the Course: **ENVIRONMENTAL SCIENCE (ENVS)**
Course Code: **UGMATHAECC-II**

Course Objectives:

After completion of this course the student will be able to

CO No.	Course Objectives:
CO 1:	Remembers and understands the concept, components and function of natural resources and ecosystems.
CO 2:	Understand and evaluate the Cause, effects and control measures of various environmental pollutants.
CO 3:	Understand the basic idea about the disasters and its management.
CO 4:	Understand and apply the knowledge about the social, environmental issues and environmental legislation.

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes:	Cognitive Level	PO Addressed	PSOs Addressed
CO 1:	Define and demonstrate the concept, components and function of natural resources and ecosystems.	R, U	PO1	PSO1
CO 2:	Define, illustrate and analyse the cause, effects and control measures of various environmental pollutants.	R, U, An	PO 3	PSO1, PSO4
CO 3:	Demonstrate the basic idea about the disasters and its management.	U	PO 3	PSO1
CO 4:	Illustrate and apply the knowledge about the social, environmental issues and environmental legislation.	U, Ap	PO 4	PSO1, PSO2
CO 5:	Define, demonstrate and evaluate the impact of human population on the Environment	R, U, E	PO 6	PSO1, PSO3

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SEMESTER – II
Name of the Course: **Real Analysis**
Course Code: **UGMATHCC03**

Course Objectives (UGMATHCC03)

The prime objectives of the course are:

- To develop a deep and rigorous understanding of real line R.
- Define terms to prove the results about convergence and divergence of sequences and series of real numbers.
- To understand the concept of sets and elements, Definition of a sequence and subsequence.
- To introduce the concepts for understanding and analyzing abstract mathematics on the metric space.

Course Outcomes (UGMATHCC03)

After completing the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Describe the real line as a complete, ordered field.	U	PO1, PO2, PO3	PSO1
CO 2	Use the definitions of convergence as they apply to sequences, and series.	R, Ap	PO3, PO5	PSO2
CO 3	Determine the basic topological properties of subsets of the real numbers.	E	PO3, PO4, PO5	PSO3
CO 4	Plot the convergence of sequences and series of different test on computer.	An, E	PO4, PO6	PSO4

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SEMESTER – II
Name of the Course: **Differential Equations & Vector Calculus**
Course Code: **UGMATHCC04**

Course Objectives (UGMATHCC04)

- The main objective of this course is to introduce the students to the exciting world of differential equations, mathematical modeling and their applications.
- Evaluate first order differential equations including separable, homogeneous, exact, and linear.
- Show existence and uniqueness of solutions.
- Solve second order and higher order linear differential equations.
- Create and analyze mathematical models using higher order differential equations to solve application problems such as harmonic oscillator and circuits.

Course Outcomes (UGMATHCC04)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Find general solution of homogenous and non-homogenous equation of higher order and their super position.	R	PO1, PO2, PO3	PSO1
CO 2	Find power series solutions of differential equations, and develop the ability to apply differential equations to significant applied and/or theoretical problems.	R, Ap	PO3, PO5	PSO2
CO 3	Describe Euler's equation, method of undetermined coefficients and method of variation of parameters.	E	PO3, PO4, PO5	PSO3
CO 4	Analyse vector functions (graphically or analytically) to find derivatives, tangent lines, integrals, arc length, and curvature.	An	PO4, PO6	PSO4
CO 5	Demonstrate their understanding of how physical phenomena are modelled by differential equations and dynamical systems. Implement solution methods using appropriate technology.	C	PO4, PO6	PSO5

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SEMESTER – III
Name of the Course: **Theory of Real Functions & Introduction to Metric Spaces**
Course Code: **UGMATHCC05**

Course Objectives (UGMATHCC05)

The prime objectives of the course are:

- To study the real valued functions that would develop an analytical ability to have a more matured perspective of the key concepts of calculus, namely, limits, continuity, differentiability and their applications.
- Understand the concepts of analysis which evidently rely on the notion of distance.
- To develop the usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.

Course Outcomes (UGMATHCC05)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Understand the sequential approaches of limit, continuity, uniform continuity and some important properties.	U	PO1, PO2, PO3	PSO1

CO 2	Recognize the difference between pointwise and uniform convergence of a sequence of functions	R	PO1, PO2, PO3	PSO1
CO 4	Recall the defining properties of a metric space, and determine whether a given function defines a metric and get familiarize with open sets, closed sets and Cantor set.	R, U	PO1, PO2, PO3	PSO1
CO 3	Apply the Mean Value Theorem and the Fundamental Theorem of Calculus to problems in the context of real analysis.	Ap, E	PO3, PO4, PO5	PSO3

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SEMESTER – III
Name of the Course: **Group Theory I**
Course Code: **UGMATHCC06**

Course Objectives (UGMATHCC06)

The prime objectives of the study are:

- To introduce the fundamental theory of groups and their homomorphisms.
- Understand the symmetric groups and group of symmetries.
- Understand the Fermat's Little theorem as a consequence of the Lagrange's theorem on finite groups.

Course Outcomes (UGMATHCC06)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understand the External direct product of a finite groups, finite abelian groups and Cauchy's theorem.	U	PO1, PO2, PO3	PSO1
CO2	Understand and classify the permutation of a group, centre of a group, Lagrange's theorem and Fermat's Little theorem.	U, An	PO4, PO6	PSO4
CO3	Apply different properties of group homomorphisms and isomorphisms theorems and Cayley's theorem in solving problems.	Ap, C	PO4, PO6	PSO4
CO4	Develop the ability to graphically or mathematically analyse the different theorem on Group by presentation.	C	PO4, PO6	PSO5

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SEMESTER – III
Name of the Course: **Numerical Methods**
Course Code: **UGMATHCC07**

Course Objectives (UGMATHCC07)

The prime objectives of the course are:

- To develop an understanding of the elements of error analysis for numerical methods and certain proofs.
- The main objective of this course is to provide students with an introduction to the field of numerical analysis.
- Derive appropriate numerical methods to solve problems based on interpolation.
- Derive appropriate numerical methods to solve problems based on probability.
- Prove results for various numerical root finding methods.

Course Outcomes (UGMATHCC07)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Implement a variety of numerical algorithms using appropriate technology.	R, U	PO1, PO2, PO3	PSO1
CO 2	Compare the viability of different approaches to the numerical solution of problems arising in roots of solution of non-linear equations, interpolation and approximation.	E	PO3, PO4, PO5	PSO3
CO 3	Analyse the error incumbent in any such numerical approximation.	An	PO4, PO6	PSO4
CO 4	Understand graphically or numerically analyse the different methods of Numerical method by computer practical.	U, An	PO4, PO6	PSO4
CO 5	Numerical differentiate and integrate, solution of linear systems using different method.	C	PO4, PO6	PSO5

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SEMESTER – IV
Name of the Course: **Riemann Integration and Series of Functions**
Course Code: **UGMATHCC08**

Course Objectives (UGMATHCC08)

The prime objectives of the course are:

- To understand the integration of bounded functions on a closed and bounded interval and its extension to the cases where either the interval of integration is infinite, or the integrand has infinite limits at a finite number of points on the interval of integration.
- To understand the sequence and series of real valued functions, and an important class of series of functions (i.e., power series).

Course Outcomes (UGMATHCC08)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Develop a knowledge about Riemann Integration, Fourier series and Power series, hence their properties and applications.	U	PO1, PO2, PO3	PSO1
CO 2	Recognize the difference between pointwise and uniform convergence of a sequence of functions.	R	PO1, PO2, PO3	PSO1
CO 3	Illustrate the effect of uniform convergence on the limit function with respect to continuity, differentiability, and integrability.	U	PO1, PO2, PO3	PSO1
CO 4	Demonstrate graphically or analytically analyse integrability conditions, the sequence of functions, series of functions and their natures by presentation.	U, Ap	PO3, PO5	PSO2

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SEMESTER – IV
Name of the Course: **Multivariate Calculus**
Course Code: **UGMATHCC09**

Course Objectives (UGMATHCC09)

The prime objectives of the course are:

- To understand the extension of the studies of single variable differential and integral calculus to functions of two or more independent variables.
- Expertise the students to make use of Computer Algebra Systems by which these concepts may be analyzed and visualized to have a better understanding.
- To become aware of applications of multivariable calculus tools in physics, economics, optimization.
- Understand the architecture of curves and surfaces in plane and space, etc.

Course Outcomes (UGMATHCC09)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Evaluate double and triple integrals over rectangular and non-rectangular region and volume by triple integrals in cylindrical and spherical coordinates.	E	PO3, PO4, PO5	PSO3
CO2	Demonstrate their ability to graphically or numerically analyze Partial differentiation, condition for differentiability relation between divergence theorem by presentation.	Ap, E	PO3, PO4, PO5	PSO3

CO3	Analyze the fundamental theorem of calculus and see their relation in calculus, leading to the more generalized version of Stokes' theorem in the setting of differential forms.	U, An	PO4, PO6	PSO4
CO4	Analyze functions of several variables to find limit, continuity and differentiability.	An	PO4, PO6	PSO4
CO5	Differentiate vector fields, determine gradient vector fields and find potential functions.	C	PO4, PO6	PSO5

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SEMESTER – IV
Name of the Course: **Ring Theory and linear Algebra I**
Course Code: **UGMATHCC10**

Course Objectives (UGMATHCC10)

The prime objectives of the course are:

- To understand the Ring theory and domain.
- To introduce the fundamental theory of two objects, namely - rings and vector spaces, and their corresponding homomorphisms.
- To determine the eigen values and eigen vectors.
- To understand the concept of Algebra of linear transformations and matrices.

Course Outcomes (UGMATHCC10)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Assess properties implied by the definitions of rings, factor rings, prime and maximal ideals.	U, Ap	PO3, PO5	PSO2
CO 2	Use the concepts of isomorphism and homomorphism for rings.	Ap	PO3, PO5	PSO2
CO 3	Use the definition and properties of linear transformations and matrices of linear transformations and change of basis, including kernel, range and isomorphism.	R, Ap	PO3, PO5	PSO2
CO 4	Analyse and demonstrate examples of ideals and quotient rings.	An, E	PO4, PO6	PSO4
CO 5	Demonstrate graphically or analytically analyze prime and maximal ideals, homomorphism and isomorphism theorem on rings and vector spaces by presentation.	C	PO4, PO6	PSO5

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SEMESTER – V
Name of the Course: **Partial Differential Equations and Applications**
Course Code: **UGMATHCC11**

Course Outcomes (UGMATHCC11)

The prime objectives of the course are:

- To form and solve partial differential equations and use them in solving some physical problems.
- To derive heat and wave equations in 2D and 3D.
- Find the solutions of PDEs are determined by conditions at the boundary of the spatial domain and initial conditions at time zero.
- Understand the technique of separation of variables to solve PDEs and analyze the behaviour of solutions in terms of eigen function expansions.

Course Outcomes (UGMATHCC11)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Be familiar with the modelling assumptions and derivations that lead to PDEs.	Ap	PO3, PO5	PSO2
CO 2	Recognize the major classification of PDEs and the qualitative differences between the classes of equations.	U, An	PO4, PO6	PSO4
CO 3	Demonstrate graphically or analytically analyze the solution of Cauchy problem, characteristic for PDE and solution of Heat equation by python languages.	An, C	PO4, PO6	PSO4
CO 4	Be competent in solving linear PDEs using classical solution methods.	C	PO4, PO6	PSO5

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SEMESTER – V
Name of the Course: **Group Theory II**
Course Code: **UGMATHCC12**

Course Objectives (UGMATHCC12)

The prime objectives of the course are:

- To develop an in-depth understanding of one of the most important branch of the abstract algebra with applications to practical real-world problems.
- Understand the classification of all finite abelian groups.
- Understand Sylow Theorems, Cauchy's theorem and simplicity of An for n ≥5.

Course Outcomes (UGMATHCC12)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Explain the concept of group homomorphism, isomorphism and automorphism.	U, E	PO3, PO4, PO5	PSO3
CO 2	Infer the properties of external and internal direct product and fundamental theorem of finite abelian groups, conjugates, the Class Equation, p-groups, Cayley's theorem and Sylow's theorems.	An	PO4, PO6	PSO4
CO 3	Derive and apply Sylow Theorems, Cauchy's theorem and simplicity of An for n $\geq$5.	An, E	PO4, PO6	PSO4
CO 4	Design graphically or analytically analyse the application of factor groups to automorphism groups, Sylow's theorem and consequences, simplicity of alternating groups and conjugacy in Sn by presentation.	C	PO4, PO6	PSO5

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SEMESTER – V
Name of the Course: **Linear Programming**
Course Code: **UGMATHDSE01**

Course Outcomes (UGMATHDSE01)

The prime objectives of the course are:

- To develop the ideas underlying the Simplex Method for Linear Programming Problem, as an important branch of Operations Research.
- Understand the Linear programming problems with applications to transportation, assignment and game problem.
- Understand the application of linear programming problems in manufacturing resource planning and financial sectors.

Course Outcomes(UGMATHDSE01)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Formulate optimization problems and solve them using different methods.	C	PO4, PO6	PSO5
CO 2	Place a Primal linear programming problem into standard form and use the Simplex Method or Revised Simplex Method to solve it and find the dual, and identify and interpret the solution of the Dual Problem from the final tableau of the Primal problem.	E, C	PO4, PO6	PSO5

CO 3	Explains the Transportation Problem and Assignment Problem, formulate them as an LPP and hence solve the problem.	E, C	PO4, PO6	PSO5
CO 4	To understand the theory of games for solving simple games.	U, C	PO4, PO6	PSO5

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SEMESTER – V
Name of the Course: **Probability and Statistics**
Course Code: **UGMATHDSE02**

Course Objectives (UGMATHDSE02)

The prime objectives of the course are:

- To make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness.
- To render the students to several examples and exercises that blend their everyday experiences with their scientific interests.
- To extend and formalize knowledge of the theory of probability and use of Baye's theorem.
- To inculcate the concepts of random variables, mathematical expectation and correlation.
- Fostering the concept of discrete and continuous probability distributions.

Course Outcomes (UGMATHDSE02)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Compute probabilities and conditional probabilities in appropriate ways.	An	PO4, PO6	PSO4
CO 2	Represent and statistically analyse data both graphically and numerically.	An, E	PO4, PO6	PSO4
CO 3	Demonstrate the ability of conditional probabilities statistically analyse data both graphically and numerically by presentation.	E, C	PO4, PO6	PSO5
CO 4	Solve word problems using combinatorial analysis.	C	PO4, PO6	PSO5

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SEMESTER – VI
Name of the Course: **Metric Spaces and Complex Analysis**
Course Code: **UGMATHCC13**

Course Objectives (UGMATHCC13)

The prime objectives of the course are:

- Understand the concepts of analysis which evidently rely on the notion of distance.
- To develop the usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.
- To introduce the basic ideas of analysis for complex functions in complex variables with visualization through relevant practicals.
- Understand the Cauchy's theorems, series expansions and calculation of residues.

Course Outcomes (UGMATHCC13)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	PSOs Addressed	PSOs Addressed
CO 1	Conceive the concepts of analytic functions and will be familiar with the elementary complex functions and their properties, and apply the concept and consequences of analyticity and the Cauchy Riemann equations and of results on harmonic and entire functions including the fundamental theorem of algebra.	R, U	PO1, PO2, PO3	PSO1
CO 2	Applies the theory into application of the power series expansion of analytic functions, and understand the basic methods of complex integration and its application in contour integration.	U, Ap	PO3, PO5	PSO2
CO 3	Demonstrate the knowledge of Cauchy sequences, Cantor's theorem, Heine-Borel property, contracting mapping, Homeomorphism and Banach fixed point theorem, through their application to ordinary differential equation.	U, Ap	PO3, PO5	PSO2
CO 4	Represent functions as Taylor, power and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem.	E	PO3, PO4, PO5	PSO3
CO 5	Analyse weather a sequence in a metric space is convergent or not.	An	PO4, PO6	PSO4

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SEMESTER – VI
Name of the Course: **Ring Theory and Linear Algebra II**
Course Code: **UGMATHCC14**

Course Objectives (UGMATHCC14)

The prime objectives of the study are:

- Introduce the basic concepts of ring of polynomials and irreducibility tests for polynomials over ring of integers, used in finite fields with applications on cryptography.
- Emphasize the application of techniques using the adjoint of linear operator and their properties to least squares approximation and minimal solutions to systems of linear equations.
- Understand the unique factorization domain and its applications, Cayley Hamilton theorem and its consequences, orthogonal projections and spectral theorem.

Course Outcomes (UGMATHCC14)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	PSOs Addressed	PSOs Addressed
CO 1	Demonstrate knowledge of polynomial ring, integral domain, unique factorization domain and Euclidean domain.	U	PO1, PO2, PO3	PSO1
CO 2	Interpret the knowledge of dual space and basis, eigen space of linear operator and the minimal polynomial for a linear operator.	R, U	PO1, PO2, PO3	PSO1
CO 3	Develop the knowledge of inner product space, least squares approximation, normal and self-adjoint operator, spectral theorem.	Ap	PO3, PO5	PSO2
CO 4	Apply unique factorization domain and its applications, Cayley Hamilton theorem and its consequences, orthogonal projections and spectral theorem.	Ap	PO3, PO5	PSO2

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SEMESTER – VI
Name of the Course: **Mechanics**
Course Code: **UGMATHDSE03**

Course Objectives (UGMATHDSE03)

The prime objectives of the course are:

- Understand the various concepts of physical quantities and the related effects on different bodies using mathematical techniques.
- Emphasize knowledge building for applying mathematics in physical world.

- To understand the concept of different forces and moments and their equilibrium with reference to a coordinate system.
- To widen appreciation of the variety of phenomena covered by mechanics and the techniques available to handle them.

Course Outcomes (UGMATHDSE03)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Understand the virtual work, stable and unstable equilibrium.	R, U	PO1, PO2, PO3	PSO1
CO 2	Understand degree of freedom, D'Alembert's Principle, compound pendulum and conservation of momentum and energy.	U	PO1, PO2, PO3	PSO1
CO 3	Solve the problems on stability of nearly orbit, motion in a particle in 3D and motion on a smooth sphere, cone and any surface.	E	PO4, PO6	PSO4

R= remembering, U = understanding, Ap = applying, An = analysing, E = evaluating, and C = creating

SEMESTER – VI
Name of the Course: **Bio Mathematics**
Course Code: **UGMATHDSE04**

Course Objectives (UGMATHDSE04)

The prime objectives of the course are:

- Understand the scientific study of normal functions in living systems.
- Exposure to nonlinear differential equations with examples such as heartbeat, chemical reactions and nerve impulse transmission.
- Understand the basic concepts of the probability to understand molecular evolution and genetics have also been applied.

Course outcomes (UGMATHDSE04)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Demonstrate knowledge of SI, SIR, SIRS and SIC.	U	PO1, PO2, PO3	PSO1
CO 2	Illustrate knowledge about different types of models and applications.	U, Ap	PO3, PO4, PO5	PSO3
CO 3	Demonstrate the knowledge of Growth model, decay model, lake pollution model limited growth of population and battle model by practical.	Ap, E	PO3, PO4, PO5	PSO3

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SEMESTER – VI
Name of the Course: **Point Set Topology**
Course Code: **UGMATHDSE04**

Course Objectives (UGMATHDSE04)

The prime objectives of the course are:

- Understand the concept of countable and uncountable sets, and some related basic theorems.
- Introduce the students to topological spaces, basis and sub-basis, connected and path connected spaces.
- Understand the compact spaces, compact sets in R, compactness in metric spaces.

Course Outcome (UGMATHDSE04)

After completion of the syllabus, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Define and illustrate the concept of countable set and uncountable set, cardinal numbers and cardinal arithmetic, Zorns lemma and ordinal numbers.	R, U	PO1, PO2, PO3	PSO1
CO 2	Demonstrate the concept of topological spaces and continuous functions, product topology and quotient topology, metric topology and Baire category theorem.	U	PO1, PO2, PO3	PSO1
CO 3	Define connectedness, compactness, and totally bounded spaces prove a selection of related theorems.	R, U	PO1, PO2, PO3	PSO1
CO 4	Students will demonstrate the ability of topological spaces and analyze some important theorem by presentation.	An	PO3, PO5	PSO2

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Generic Elective Subjects Syllabus
Name of the Course: **Algebra**
Course Code: **UGMATHGE01**

Course Objectives (UGMATHGE01)

The prime objectives of the course are:

- To work with matrices and determine if a given square matrix is invertible.
- Learn to solve systems of linear equations and application problems requiring them.
- Compute determinants and know their properties.
- To find and use eigenvalues and eigenvectors of a matrix.
- Learn about and work with vector spaces and subspaces.

Course Outcomes (UGMATHGE01)

After completion of the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Define algebraic structures	R, U	PO1, PO2, PO3	PSO1
CO 2	Classify substructures.	U	PO1, PO2, PO3	PSO1
CO 3	Analyze a given structure in detail.	An	PO3, PO5	PSO2
CO 4	Compare structures.	E	PO4, PO6	PSO4
CO 5	Develop new structures based on given structures.	C	PO4, PO6	PSO5

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Generic Elective Subjects Syllabus
Name of the Course: **Calculus, Geometry and Differential Equations**
Course Code: **UGMATHGE02**

Course Objectives (UGMATHGE02)

The prime objectives of the course are:

- To introduce the basic tools of calculus and geometric properties of different conic sections which are helpful in understanding their applications in planetary motion, design of telescope and to the real-world problems.
- To carry out the hand on sessions in computer lab to have a deep conceptual understanding of the above tools to widen the horizon of students' self-experience.
- To introduce the students to the exciting world of differential equations, mathematical modelling and their applications.

Course Outcomes (UGMATHGE02)

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

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Define vector field, divergence and curl and solve related problems.	R, U	PO1, PO2, PO3	PSO1
CO 2	Solve first order differential equations utilizing the standard techniques for separable, exact, linear, homogeneous, or Bernoulli cases.	Ap	PO3, PO5	PSO2
CO 3	Solve linear differential equations of both first and second order and apply differential equation techniques to predict the behaviour of certain phenomena.	Ap, An	PO4, PO6	PSO4
CO 4	Apply specific methodologies, techniques and resources to conduct research and produce innovative results in the area of specialisation.	Ap, An	PO4, PO6	PSO4

CO 5	Extract information from differential models in order to interpret reality and identify real phenomena as models of differential equations.	C	PO4, PO6	PSO5

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Generic Elective Subjects Syllabus
Name of the Course: **Numerical Methods**
Course Code: **UGMATHGE03**

Course Objectives (UGMATHGE03)

The prime objectives of the course are:

- To comprehend various computational techniques to find approximate value for possible root(s) of non-algebraic equations, to find the approximate solutions of system of linear equations and ordinary differential equations.
- Emphasise the use of Computer Algebra System by which the numerical problems can be solved both numerically and analytically, and to enhance the problem solving skills.

Course Outcomes (UGMATHGE03)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	PSOs Addressed	PSOs Addressed
CO 1	Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of differential equations.	R, U	PO1, PO2, PO3	PSO1
CO 2	Analyse and evaluate the accuracy of common numerical methods.	An, E	PO3, PO4, PO5	PSO3

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Generic Elective Subjects Syllabus
Name of the Course: **Group Theory**
Course Code: **UGMATHGE04**

Course Objectives (UGMATHGE04)

The prime objectives of the course are:

- To introduce the fundamental theory of groups and their homomorphisms.
- Understand symmetric groups and group of symmetries in detail.
- Understand Fermat's Little theorem as a consequence of the Lagrange's theorem on finite groups.
- Understand the abstract algebra with applications to practical real-world problems.

Course Outcomes (UGMATHGE04)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Extend group structure to finite permutation groups (Caley Hamilton Theorem).	R, U	PO1, PO2, PO3	PSO1
CO 2	Generate groups given specific conditions.	E	PO3, PO4, PO5	PSO3
CO 3	Generate symmetry using group theory.	E	PO3, PO4, PO5	PSO3
CO 4	Analyse algebra of electrical circuits, and the algebra of logic.	An, C	PO4, PO6	PSO4

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RAMAKRISHNA MISSION VIVEKANANDA CENTENARY COLLEGE

RAHARA, KOLKATA-700118

DEPARTMENT OF MATHEMATICS

SESSION 2019-20

Programme Outcomes, Programme Specific Outcomes, Course Objectives and Course Outcomes of UG Syllabus for B.Sc. Mathematics

Principal
Ramakrishna Mission
Vivekananda Centenary College
Rahara, Kolkata-700 118

PROGRAM OUTCOMES

After completion of the B.Sc. Degree program, the students will be able to

PO No.	Program Outcomes	Cognitive Level
PO 1	Recognize the scientific tempers and attitudes, which in turn can prove to be beneficial for the society since the scientific developments can make a nation or society to grow at a rapid pace.	R
PO 2	Understand scientific knowledge and exchange ideas with other stakeholders; make people aware about sustainable utilization of resources with ethical approach.	U
PO 3	Understand and apply the issues of environmental contexts and sustainable development as a basic interdisciplinary concern.	U, Ap
PO 4	Create the ability to perform experiments and to analyse & interpret the obtained accurate results and thus gain the ability to solve problems, to involve in critical, independent, and creative thinking.	An, E, C
PO 5	Possess expertise to apply and formulate ideas which will provide them competitive advantage in pursuing higher studies from India or abroad; and seek jobs in academia, research or industries.	Ap, E
PO 6	Assemble the acquired in-depth knowledge of applied subjects towards the inculcation of professional and employment skills so that students can make a career and become an entrepreneur in diverse fields.	C

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PROGRAMME SPECIFIC OUTCOMES

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

PSO No.	Program Specific Outcomes	Cognitive Level
PSO1	Explain the core ideas and the techniques of mathematics at the college level and recognize the power of abstraction and generalization, and to carry out investigative mathematical work with independent judgment.	R, U
PSO2	Set up mathematical models of real-world problems, obtain solutions in structured and analytical approaches, carry out objective analysis and prediction of quantitative information with independent judgment.	Ap
PSO3	Learn numerical aptitude applying both qualitative and quantitative knowledge for their future career and being a responsible citizen towards their community and a sustainable environment.	Ap, E
PSO4	Communicate to lay audiences and arouse their interest in the beauty and precision of mathematical arguments and science and recognize the importance of compliance with the ethics of science.	An, C
PSO5	Collaborate effectively in team work and team building, conduct self-evaluation, and continuously enrich themselves through lifelong learning.	C

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Course Structure: Semester-wise distribution of Courses

Honours

Semester -I		
Course Code	Title	Credits
UGAECC-I	English Communication	2
UGMATHCC01	Calculus, Geometry & Differential Equation & Practical	4+2
UGMATHCC02	Algebra & Tutorial	5+1
Semester-II		
UGAECC-II	Environmental Science (Envs)	2
UGMATHCC03	Real Analysis & Practical	4+2
UGMATHCC04	Differential Equations & Vector Calculus & Practical	5+1
Semester -III		
UGMATHCC05	Theory of Real Functions & Introduction to Metric Spaces	65+1
UGMATHCC06	Group Theory I & Tutorial	5+1
UGMATHCC07	Numerical Methods & Practical - Numerical Methods Lab	4 +2
Semester -IV		
UGMATHCC08	Riemann Integration and Series of Functions	5+1
UGMATHCC09	Multivariate Calculus	5+1
UGMATHCC10	Ring Theory and Linear Algebra I	5+1
Semester -V		
UGMATHCC11	Partial Differential Equations and Applications & Practical	4+2
UGMATHCC12	Group Theory II & Tutorial	5+1
Electives		
UGMATHDSE1	Linear Programming & Tutorial	5+1
UGMATHDSE2	Probability and Statistics & Tutorial	5+1
Semester -VI		
UGMATHCC13	Metric Spaces and Complex Analysis & Tutorial	5+1
UGMATHCC14	Ring Theory and Linear Algebra II & Tutorial	5+1
Electives Choose any two of the following courses		
UGMATHDSE3 UGMATHDSE4	1.Mechanics & Tutorial	5+1
	2.Bio Mathematics & Practical	4+2
	3.Point Set Topology & Tutorial	5+1
Skill Enhancement Subjects		
UGMATHSEC1	Logic and Sets	2
UGMATHSEC2	Python 3.4.3	2
Generic Elective Subjects Syllabus		
UGMATHGE01	Algebra & Tutorial	5+1
UGMATHGE02	Calculus, Geometry and Differential Equation & Tutorial	5+1
UGMATHGE03	Numerical Methods & Tutorial	5+1
UGMATHGE04	Group Theory & Tutorial	5+1
GRAND TOTAL		**140**

SEMESTER – I
Name of the Course: **English Communication**
Course Code: **UGMATHAECC-I**

Course Objectives (UGMATHAECC-I)

The prime objectives of the course are:

- In-depth knowledge of language skills – Listening, Speaking, Reading and Writing.
- In-depth knowledge of grammar and their applications in Speaking, Reading and Writing Skills.
- To provide expertise and consultancy services in the private and public sector and to be an entrepreneur/professional consultant.
- To opt for higher education, research and to be a life-long learner.
- To provide value based and ethical leadership to the profession and social life.

Course Outcome (UGMATHAECC-I)

By the end of the program, the students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Engage in self-directed English language learning.	R,	PO1, PO2, PO3	PSO 1
CO 2	Be responsible and ethical English users.	R, U	PO1, PO2, PO3	PSO 1
CO 3	Enhance their English language proficiency in the aspects of reading, writing, listening and speaking.	R, U	PO1, PO2, PO3	PSO 1
CO 4	Develop academic literacy required for undergraduate learning, further studies and research.	Ap	PO3, PO5	PSO 2
CO 5	Apply the requisite communicative skills and strategies to future careers.	Ap,	PO3, PO5	PSO 2
CO 6	Gain an insight into cultural literacy and cross-cultural awareness.	Ap	PO3, PO5	PSO 2

SEMESTER – I
Name of the Course: **Calculus, Geometry & Differential Equation**
Course Code: **UGMATHCC01**

Course Objectives (UGMATHCC01)

The prime objectives of the course are:

- To introduce the students to the exciting world of differential equations, mathematical modelling and their applications.

- To evaluate integration of irrational functions and improper integrals.
- To understand the concepts of double and triple integration.
- Calculate definite integrals that may involve logarithms, exponentials, polynomials, and powers by using the Fundamental Theorem of Calculus.

Course Outcomes (UGMATHCC01)

After completing the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSO Addressed
CO1	Recall the basic concepts of conics and classification of quadrics.	U, R	PO1, PO2, PO3	PSO1
CO2	Construct a variety of differential equations analytically and numerically.	Ap	PO3, PO5	PSO2
CO3	Measure/calculate length, perimeter, area, volume of surface of revolution of a curve and techniques of sketching conics.	Ap, E	PO3, PO4, PO5	PSO3
CO4	Develop ability to graphically analyze functions by computer practical.	C	PO4, PO6	PSO5

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SEMESTER – I
Name of the Course: **Algebra**
Course Code: **UGMATHCC02**

Course Objectives (UGMATHCC02)

The prime objectives of the course are:

- To introduce the basic tools of theory of equations, complex numbers, number theory and matrices.
- To understand the connection of algebra with the real-world problems.
- Perform matrix algebra with applications to computer graphics.
- Learn to solve systems of linear equations and application problems requiring them.

Course Outcomes (UGMATHCC02)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understand complex numbers, way of representing numbers, relationships among numbers, different method for solving polynomial equations.	Ap	PO3, PO5	PSO2
CO2	Solve linear equations.	Ap	PO3, PO5	PSO2
CO3	Demonstrate their ability to graphically or numerically analyze functions by presentation.	C	PO4, PO6	PSO5

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SEMESTER – II
Name of the Course: **ENVIRONMENTAL SCIENCE (ENVS)**
Course Code: **UGMATHAECC-II**

Course Objectives:

After completion of this course the student will be able to

CO No.	Course Objectives:
CO 1:	Remembers and understands the concept, components and function of natural resources and ecosystems.
CO 2:	Understand and evaluate the Cause, effects and control measures of various environmental pollutants.
CO 3:	Understand the basic idea about the disasters and its management.
CO 4:	Understand and apply the knowledge about the social, environmental issues and environmental legislation.

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes:	Cognitive Level	PO Addressed	PSOs Addressed
CO 1:	Define and demonstrate the concept, components and function of natural resources and ecosystems.	R, U	PO1	PSO1
CO 2:	Define, illustrate and analyse the cause, effects and control measures of various environmental pollutants.	R, U, An	PO 3	PSO1, PSO4
CO 3:	Demonstrate the basic idea about the disasters and its management.	U	PO 3	PSO1
CO 4:	Illustrate and apply the knowledge about the social, environmental issues and environmental legislation.	U, Ap	PO 4	PSO1, PSO2
CO 5:	Define, demonstrate and evaluate the impact of human population on the Environment	R, U, E	PO 6	PSO1, PSO3

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SEMESTER – II
Name of the Course: **Real Analysis**
Course Code: **UGMATHCC03**

Course Objectives (UGMATHCC03)

The prime objectives of the course are:

- To develop a deep and rigorous understanding of real line R.
- Define terms to prove the results about convergence and divergence of sequences and series of real numbers.
- To understand the concept of sets and elements, Definition of a sequence and subsequence.
- To introduce the concepts for understanding and analyzing abstract mathematics on the metric space.

Course Outcomes (UGMATHCC03)

After completing the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Describe the real line as a complete, ordered field.	U	PO1, PO2, PO3	PSO1
CO 2	Use the definitions of convergence as they apply to sequences, and series.	R, Ap	PO3, PO5	PSO2
CO 3	Determine the basic topological properties of subsets of the real numbers.	E	PO3, PO4, PO5	PSO3
CO 4	Plot the convergence of sequences and series of different test on computer.	An, E	PO4, PO6	PSO4

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SEMESTER – II
Name of the Course: **Differential Equations & Vector Calculus**
Course Code: **UGMATHCC04**

Course Objectives (UGMATHCC04)

- The main objective of this course is to introduce the students to the exciting world of differential equations, mathematical modeling and their applications.
- Evaluate first order differential equations including separable, homogeneous, exact, and linear.
- Show existence and uniqueness of solutions.
- Solve second order and higher order linear differential equations.
- Create and analyze mathematical models using higher order differential equations to solve application problems such as harmonic oscillator and circuits.

Course Outcomes (UGMATHCC04)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Find general solution of homogenous and non-homogenous equation of higher order and their super position.	R	PO1, PO2, PO3	PSO1
CO 2	Find power series solutions of differential equations, and develop the ability to apply differential equations to significant applied and/or theoretical problems.	R, Ap	PO3, PO5	PSO2
CO 3	Describe Euler's equation, method of undetermined coefficients and method of variation of parameters.	E	PO3, PO4, PO5	PSO3
CO 4	Analyse vector functions (graphically or analytically) to find derivatives, tangent lines, integrals, arc length, and curvature.	An	PO4, PO6	PSO4
CO 5	Demonstrate their understanding of how physical phenomena are modelled by differential equations and dynamical systems. Implement solution methods using appropriate technology.	C	PO4, PO6	PSO5

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SEMESTER – III
Name of the Course: **Theory of Real Functions & Introduction to Metric Spaces**
Course Code: **UGMATHCC05**

Course Objectives (UGMATHCC05)

The prime objectives of the course are:

- To study the real valued functions that would develop an analytical ability to have a more matured perspective of the key concepts of calculus, namely, limits, continuity, differentiability and their applications.
- Understand the concepts of analysis which evidently rely on the notion of distance.
- To develop the usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.

Course Outcomes (UGMATHCC05)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Understand the sequential approaches of limit, continuity, uniform continuity and some important properties.	U	PO1, PO2, PO3	PSO1

CO 2	Recognize the difference between pointwise and uniform convergence of a sequence of functions	R	PO1, PO2, PO3	PSO1
CO 4	Recall the defining properties of a metric space, and determine whether a given function defines a metric and get familiarize with open sets, closed sets and Cantor set.	R, U	PO1, PO2, PO3	PSO1
CO 3	Apply the Mean Value Theorem and the Fundamental Theorem of Calculus to problems in the context of real analysis.	Ap, E	PO3, PO4, PO5	PSO3

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SEMESTER – III
Name of the Course: **Group Theory I**
Course Code: **UGMATHCC06**

Course Objectives (UGMATHCC06)

The prime objectives of the study are:

- To introduce the fundamental theory of groups and their homomorphisms.
- Understand the symmetric groups and group of symmetries.
- Understand the Fermat's Little theorem as a consequence of the Lagrange's theorem on finite groups.

Course Outcomes (UGMATHCC06)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understand the External direct product of a finite groups, finite abelian groups and Cauchy's theorem.	U	PO1, PO2, PO3	PSO1
CO2	Understand and classify the permutation of a group, centre of a group, Lagrange's theorem and Fermat's Little theorem.	U, An	PO4, PO6	PSO4
CO3	Apply different properties of group homomorphisms and isomorphisms theorems and Cayley's theorem in solving problems.	Ap, C	PO4, PO6	PSO4
CO4	Develop the ability to graphically or mathematically analyse the different theorem on Group by presentation.	C	PO4, PO6	PSO5

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SEMESTER – III
Name of the Course: **Numerical Methods**
Course Code: **UGMATHCC07**

Course Objectives (UGMATHCC07)

The prime objectives of the course are:

- To develop an understanding of the elements of error analysis for numerical methods and certain proofs.
- The main objective of this course is to provide students with an introduction to the field of numerical analysis.
- Derive appropriate numerical methods to solve problems based on interpolation.
- Derive appropriate numerical methods to solve problems based on probability.
- Prove results for various numerical root finding methods.

Course Outcomes (UGMATHCC07)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Implement a variety of numerical algorithms using appropriate technology.	R, U	PO1, PO2, PO3	PSO1
CO 2	Compare the viability of different approaches to the numerical solution of problems arising in roots of solution of non-linear equations, interpolation and approximation.	E	PO3, PO4, PO5	PSO3
CO 3	Analyse the error incumbent in any such numerical approximation.	An	PO4, PO6	PSO4
CO 4	Understand graphically or numerically analyse the different methods of Numerical method by computer practical.	U, An	PO4, PO6	PSO4
CO 5	Numerical differentiate and integrate, solution of linear systems using different method.	C	PO4, PO6	PSO5

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SEMESTER – IV
Name of the Course: **Riemann Integration and Series of Functions**
Course Code: **UGMATHCC08**

Course Objectives (UGMATHCC08)

The prime objectives of the course are:

- To understand the integration of bounded functions on a closed and bounded interval and its extension to the cases where either the interval of integration is infinite, or the integrand has infinite limits at a finite number of points on the interval of integration.
- To understand the sequence and series of real valued functions, and an important class of series of functions (i.e., power series).

Course Outcomes (UGMATHCC08)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Develop a knowledge about Riemann Integration, Fourier series and Power series, hence their properties and applications.	U	PO1, PO2, PO3	PSO1
CO 2	Recognize the difference between pointwise and uniform convergence of a sequence of functions.	R	PO1, PO2, PO3	PSO1
CO 3	Illustrate the effect of uniform convergence on the limit function with respect to continuity, differentiability, and integrability.	U	PO1, PO2, PO3	PSO1
CO 4	Demonstrate graphically or analytically analyse integrability conditions, the sequence of functions, series of functions and their natures by presentation.	U, Ap	PO3, PO5	PSO2

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SEMESTER – IV
Name of the Course: **Multivariate Calculus**
Course Code: **UGMATHCC09**

Course Objectives (UGMATHCC09)

The prime objectives of the course are:

- To understand the extension of the studies of single variable differential and integral calculus to functions of two or more independent variables.
- Expertise the students to make use of Computer Algebra Systems by which these concepts may be analyzed and visualized to have a better understanding.
- To become aware of applications of multivariable calculus tools in physics, economics, optimization.
- Understand the architecture of curves and surfaces in plane and space, etc.

Course Outcomes (UGMATHCC09)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Evaluate double and triple integrals over rectangular and non-rectangular region and volume by triple integrals in cylindrical and spherical coordinates.	E	PO3, PO4, PO5	PSO3
CO2	Demonstrate their ability to graphically or numerically analyze Partial differentiation, condition for differentiability relation between divergence theorem by presentation.	Ap, E	PO3, PO4, PO5	PSO3

CO3	Analyze the fundamental theorem of calculus and see their relation in calculus, leading to the more generalized version of Stokes' theorem in the setting of differential forms.	U, An	PO4, PO6	PSO4
CO4	Analyze functions of several variables to find limit, continuity and differentiability.	An	PO4, PO6	PSO4
CO5	Differentiate vector fields, determine gradient vector fields and find potential functions.	C	PO4, PO6	PSO5

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SEMESTER – IV
Name of the Course: **Ring Theory and linear Algebra I**
Course Code: **UGMATHCC10**

Course Objectives (UGMATHCC10)

The prime objectives of the course are:

- To understand the Ring theory and domain.
- To introduce the fundamental theory of two objects, namely - rings and vector spaces, and their corresponding homomorphisms.
- To determine the eigen values and eigen vectors.
- To understand the concept of Algebra of linear transformations and matrices.

Course Outcomes (UGMATHCC10)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Assess properties implied by the definitions of rings, factor rings, prime and maximal ideals.	U, Ap	PO3, PO5	PSO2
CO 2	Use the concepts of isomorphism and homomorphism for rings.	Ap	PO3, PO5	PSO2
CO 3	Use the definition and properties of linear transformations and matrices of linear transformations and change of basis, including kernel, range and isomorphism.	R, Ap	PO3, PO5	PSO2
CO 4	Analyse and demonstrate examples of ideals and quotient rings.	An, E	PO4, PO6	PSO4
CO 5	Demonstrate graphically or analytically analyze prime and maximal ideals, homomorphism and isomorphism theorem on rings and vector spaces by presentation.	C	PO4, PO6	PSO5

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SEMESTER – V
Name of the Course: **Partial Differential Equations and Applications**
Course Code: **UGMATHCC11**

Course Outcomes (UGMATHCC11)

The prime objectives of the course are:

- To form and solve partial differential equations and use them in solving some physical problems.
- To derive heat and wave equations in 2D and 3D.
- Find the solutions of PDEs are determined by conditions at the boundary of the spatial domain and initial conditions at time zero.
- Understand the technique of separation of variables to solve PDEs and analyze the behaviour of solutions in terms of eigen function expansions.

Course Outcomes (UGMATHCC11)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Be familiar with the modelling assumptions and derivations that lead to PDEs.	Ap	PO3, PO5	PSO2
CO 2	Recognize the major classification of PDEs and the qualitative differences between the classes of equations.	U, An	PO4, PO6	PSO4
CO 3	Demonstrate graphically or analytically analyze the solution of Cauchy problem, characteristic for PDE and solution of Heat equation by python languages.	An, C	PO4, PO6	PSO4
CO 4	Be competent in solving linear PDEs using classical solution methods.	C	PO4, PO6	PSO5

R= remembering, U = understanding, Ap = applying, An = analysing, E = evaluating, and C = creating

SEMESTER – V
Name of the Course: **Group Theory II**
Course Code: **UGMATHCC12**

Course Objectives (UGMATHCC12)

The prime objectives of the course are:

- To develop an in-depth understanding of one of the most important branch of the abstract algebra with applications to practical real-world problems.
- Understand the classification of all finite abelian groups.
- Understand Sylow Theorems, Cauchy's theorem and simplicity of An for n ≥5.

Course Outcomes (UGMATHCC12)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Explain the concept of group homomorphism, isomorphism and automorphism.	U, E	PO3, PO4, PO5	PSO3
CO 2	Infer the properties of external and internal direct product and fundamental theorem of finite abelian groups, conjugates, the Class Equation, p-groups, Cayley's theorem and Sylow's theorems.	An	PO4, PO6	PSO4
CO 3	Derive and apply Sylow Theorems, Cauchy's theorem and simplicity of An for n $\geq$5.	An, E	PO4, PO6	PSO4
CO 4	Design graphically or analytically analyse the application of factor groups to automorphism groups, Sylow's theorem and consequences, simplicity of alternating groups and conjugacy in Sn by presentation.	C	PO4, PO6	PSO5

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SEMESTER – V
Name of the Course: **Linear Programming**
Course Code: **UGMATHDSE01**

Course Outcomes (UGMATHDSE01)

The prime objectives of the course are:

- To develop the ideas underlying the Simplex Method for Linear Programming Problem, as an important branch of Operations Research.
- Understand the Linear programming problems with applications to transportation, assignment and game problem.
- Understand the application of linear programming problems in manufacturing resource planning and financial sectors.

Course Outcomes(UGMATHDSE01)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Formulate optimization problems and solve them using different methods.	C	PO4, PO6	PSO5
CO 2	Place a Primal linear programming problem into standard form and use the Simplex Method or Revised Simplex Method to solve it and find the dual, and identify and interpret the solution of the Dual Problem from the final tableau of the Primal problem.	E, C	PO4, PO6	PSO5

CO 3	Explains the Transportation Problem and Assignment Problem, formulate them as an LPP and hence solve the problem.	E, C	PO4, PO6	PSO5
CO 4	To understand the theory of games for solving simple games.	U, C	PO4, PO6	PSO5

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SEMESTER – V
Name of the Course: **Probability and Statistics**
Course Code: **UGMATHDSE02**

Course Objectives (UGMATHDSE02)

The prime objectives of the course are:

- To make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness.
- To render the students to several examples and exercises that blend their everyday experiences with their scientific interests.
- To extend and formalize knowledge of the theory of probability and use of Baye's theorem.
- To inculcate the concepts of random variables, mathematical expectation and correlation.
- Fostering the concept of discrete and continuous probability distributions.

Course Outcomes (UGMATHDSE02)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Compute probabilities and conditional probabilities in appropriate ways.	An	PO4, PO6	PSO4
CO 2	Represent and statistically analyse data both graphically and numerically.	An, E	PO4, PO6	PSO4
CO 3	Demonstrate the ability of conditional probabilities statistically analyse data both graphically and numerically by presentation.	E, C	PO4, PO6	PSO5
CO 4	Solve word problems using combinatorial analysis.	C	PO4, PO6	PSO5

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SEMESTER – VI
Name of the Course: **Metric Spaces and Complex Analysis**
Course Code: **UGMATHCC13**

Course Objectives (UGMATHCC13)

The prime objectives of the course are:

- Understand the concepts of analysis which evidently rely on the notion of distance.
- To develop the usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.
- To introduce the basic ideas of analysis for complex functions in complex variables with visualization through relevant practicals.
- Understand the Cauchy's theorems, series expansions and calculation of residues.

Course Outcomes (UGMATHCC13)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	PSOs Addressed	PSOs Addressed
CO 1	Conceive the concepts of analytic functions and will be familiar with the elementary complex functions and their properties, and apply the concept and consequences of analyticity and the Cauchy Riemann equations and of results on harmonic and entire functions including the fundamental theorem of algebra.	R, U	PO1, PO2, PO3	PSO1
CO 2	Applies the theory into application of the power series expansion of analytic functions, and understand the basic methods of complex integration and its application in contour integration.	U, Ap	PO3, PO5	PSO2
CO 3	Demonstrate the knowledge of Cauchy sequences, Cantor's theorem, Heine-Borel property, contracting mapping, Homeomorphism and Banach fixed point theorem, through their application to ordinary differential equation.	U, Ap	PO3, PO5	PSO2
CO 4	Represent functions as Taylor, power and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem.	E	PO3, PO4, PO5	PSO3
CO 5	Analyse weather a sequence in a metric space is convergent or not.	An	PO4, PO6	PSO4

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SEMESTER – VI
Name of the Course: **Ring Theory and Linear Algebra II**
Course Code: **UGMATHCC14**

Course Objectives (UGMATHCC14)

The prime objectives of the study are:

- Introduce the basic concepts of ring of polynomials and irreducibility tests for polynomials over ring of integers, used in finite fields with applications on cryptography.
- Emphasize the application of techniques using the adjoint of linear operator and their properties to least squares approximation and minimal solutions to systems of linear equations.
- Understand the unique factorization domain and its applications, Cayley Hamilton theorem and its consequences, orthogonal projections and spectral theorem.

Course Outcomes (UGMATHCC14)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	PSOs Addressed	PSOs Addressed
CO 1	Demonstrate knowledge of polynomial ring, integral domain, unique factorization domain and Euclidean domain.	U	PO1, PO2, PO3	PSO1
CO 2	Interpret the knowledge of dual space and basis, eigen space of linear operator and the minimal polynomial for a linear operator.	R, U	PO1, PO2, PO3	PSO1
CO 3	Develop the knowledge of inner product space, least squares approximation, normal and self-adjoint operator, spectral theorem.	Ap	PO3, PO5	PSO2
CO 4	Apply unique factorization domain and its applications, Cayley Hamilton theorem and its consequences, orthogonal projections and spectral theorem.	Ap	PO3, PO5	PSO2

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SEMESTER – VI
Name of the Course: **Mechanics**
Course Code: **UGMATHDSE03**

Course Objectives (UGMATHDSE03)

The prime objectives of the course are:

- Understand the various concepts of physical quantities and the related effects on different bodies using mathematical techniques.
- Emphasize knowledge building for applying mathematics in physical world.

- To understand the concept of different forces and moments and their equilibrium with reference to a coordinate system.
- To widen appreciation of the variety of phenomena covered by mechanics and the techniques available to handle them.

Course Outcomes (UGMATHDSE03)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Understand the virtual work, stable and unstable equilibrium.	R, U	PO1, PO2, PO3	PSO1
CO 2	Understand degree of freedom, D'Alembert's Principle, compound pendulum and conservation of momentum and energy.	U	PO1, PO2, PO3	PSO1
CO 3	Solve the problems on stability of nearly orbit, motion in a particle in 3D and motion on a smooth sphere, cone and any surface.	E	PO4, PO6	PSO4

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SEMESTER – VI
Name of the Course: **Bio Mathematics**
Course Code: **UGMATHDSE04**

Course Objectives (UGMATHDSE04)

The prime objectives of the course are:

- Understand the scientific study of normal functions in living systems.
- Exposure to nonlinear differential equations with examples such as heartbeat, chemical reactions and nerve impulse transmission.
- Understand the basic concepts of the probability to understand molecular evolution and genetics have also been applied.

Course outcomes (UGMATHDSE04)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Demonstrate knowledge of SI, SIR, SIRS and SIC.	U	PO1, PO2, PO3	PSO1
CO 2	Illustrate knowledge about different types of models and applications.	U, Ap	PO3, PO4, PO5	PSO3
CO 3	Demonstrate the knowledge of Growth model, decay model, lake pollution model limited growth of population and battle model by practical.	Ap, E	PO3, PO4, PO5	PSO3

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SEMESTER – VI
Name of the Course: **Point Set Topology**
Course Code: **UGMATHDSE04**

Course Objectives (UGMATHDSE04)

The prime objectives of the course are:

- Understand the concept of countable and uncountable sets, and some related basic theorems.
- Introduce the students to topological spaces, basis and sub-basis, connected and path connected spaces.
- Understand the compact spaces, compact sets in R, compactness in metric spaces.

Course Outcome (UGMATHDSE04)

After completion of the syllabus, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Define and illustrate the concept of countable set and uncountable set, cardinal numbers and cardinal arithmetic, Zorns lemma and ordinal numbers.	R, U	PO1, PO2, PO3	PSO1
CO 2	Demonstrate the concept of topological spaces and continuous functions, product topology and quotient topology, metric topology and Baire category theorem.	U	PO1, PO2, PO3	PSO1
CO 3	Define connectedness, compactness, and totally bounded spaces prove a selection of related theorems.	R, U	PO1, PO2, PO3	PSO1
CO 4	Students will demonstrate the ability of topological spaces and analyze some important theorem by presentation.	An	PO3, PO5	PSO2

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Generic Elective Subjects Syllabus
Name of the Course: **Algebra**
Course Code: **UGMATHGE01**

Course Objectives (UGMATHGE01)

The prime objectives of the course are:

- To work with matrices and determine if a given square matrix is invertible.
- Learn to solve systems of linear equations and application problems requiring them.
- Compute determinants and know their properties.
- To find and use eigenvalues and eigenvectors of a matrix.
- Learn about and work with vector spaces and subspaces.

Course Outcomes (UGMATHGE01)

After completion of the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Define algebraic structures	R, U	PO1, PO2, PO3	PSO1
CO 2	Classify substructures.	U	PO1, PO2, PO3	PSO1
CO 3	Analyze a given structure in detail.	An	PO3, PO5	PSO2
CO 4	Compare structures.	E	PO4, PO6	PSO4
CO 5	Develop new structures based on given structures.	C	PO4, PO6	PSO5

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Generic Elective Subjects Syllabus
Name of the Course: **Calculus, Geometry and Differential Equations**
Course Code: **UGMATHGE02**

Course Objectives (UGMATHGE02)

The prime objectives of the course are:

- To introduce the basic tools of calculus and geometric properties of different conic sections which are helpful in understanding their applications in planetary motion, design of telescope and to the real-world problems.
- To carry out the hand on sessions in computer lab to have a deep conceptual understanding of the above tools to widen the horizon of students' self-experience.
- To introduce the students to the exciting world of differential equations, mathematical modelling and their applications.

Course Outcomes (UGMATHGE02)

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

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Define vector field, divergence and curl and solve related problems.	R, U	PO1, PO2, PO3	PSO1
CO 2	Solve first order differential equations utilizing the standard techniques for separable, exact, linear, homogeneous, or Bernoulli cases.	Ap	PO3, PO5	PSO2
CO 3	Solve linear differential equations of both first and second order and apply differential equation techniques to predict the behaviour of certain phenomena.	Ap, An	PO4, PO6	PSO4
CO 4	Apply specific methodologies, techniques and resources to conduct research and produce innovative results in the area of specialisation.	Ap, An	PO4, PO6	PSO4

CO 5	Extract information from differential models in order to interpret reality and identify real phenomena as models of differential equations.	C	PO4, PO6	PSO5

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Generic Elective Subjects Syllabus
Name of the Course: **Numerical Methods**
Course Code: **UGMATHGE03**

Course Objectives (UGMATHGE03)

The prime objectives of the course are:

- To comprehend various computational techniques to find approximate value for possible root(s) of non-algebraic equations, to find the approximate solutions of system of linear equations and ordinary differential equations.
- Emphasise the use of Computer Algebra System by which the numerical problems can be solved both numerically and analytically, and to enhance the problem solving skills.

Course Outcomes (UGMATHGE03)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	PSOs Addressed	PSOs Addressed
CO 1	Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of differential equations.	R, U	PO1, PO2, PO3	PSO1
CO 2	Analyse and evaluate the accuracy of common numerical methods.	An, E	PO3, PO4, PO5	PSO3

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Generic Elective Subjects Syllabus
Name of the Course: **Group Theory**
Course Code: **UGMATHGE04**

Course Objectives (UGMATHGE04)

The prime objectives of the course are:

- To introduce the fundamental theory of groups and their homomorphisms.
- Understand symmetric groups and group of symmetries in detail.
- Understand Fermat's Little theorem as a consequence of the Lagrange's theorem on finite groups.
- Understand the abstract algebra with applications to practical real-world problems.

Course Outcomes (UGMATHGE04)

After completing the course, students will be able to

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Extend group structure to finite permutation groups (Caley Hamilton Theorem).	R, U	PO1, PO2, PO3	PSO1
CO 2	Generate groups given specific conditions.	E	PO3, PO4, PO5	PSO3
CO 3	Generate symmetry using group theory.	E	PO3, PO4, PO5	PSO3
CO 4	Analyse algebra of electrical circuits, and the algebra of logic.	An, C	PO4, PO6	PSO4

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RAMAKRISHNA MISSION VIVEKANANDA CENTENARY COLLEGE

RAHARA, KOLKATA-700118

DEPARTMENT OF MATHEMATICS

SESSION 2018-19

Programme Outcomes, Programme Specific Outcomes, Course Objectives and Course Outcomes of Syllabus for M.Sc. Mathematics

Principal
Ramakrishna Mission
Vivekananda Centenary College
Rahara, Kolkata-700 118

PROGRAMME OUTCOMES

After completion of the M.Sc. Degree programme, the students will be able to

PO No.	PROGRAMME OUTCOMES	Cognitive Level
PO 1	Outline and demonstrate the basic concepts by acquiring a comprehensive knowledge in the newer emerging field of knowledge.	R, U
PO 2	Perform experiments, analyse & interpret the obtained accurate results and thus gain the ability to solve problems.	Ap, An, E
PO 3	Apply and evaluate the basic ideas to their thoughts, actions, and interventions for the societal benefits through the development of entrepreneurships.	Ap, E
PO 4	Develop the ability to involve in critical, independent, and inventive thinking for the engagement in research and development on the emerging topics.	C

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PROGRAM SPECIFIC OUTCOME

At the end of the program, the student will be able to:

PSO No.	Program Specific Outcome	Cognitive Level
PSO1	Understand the nature of abstract mathematics and explore the concepts in further details.	R, U
PSO2	Apply the knowledge of mathematical concepts (both pure and applied mathematics) in interdisciplinary fields.	Ap
PSO3	Continue to acquire mathematical knowledge and skills appropriate to professional activities and demonstrate highest standards of ethical issues in mathematics.	R, An
PSO4	Apply the knowledge of mathematical software and tools for treating complex mathematical problems and scientific investigations and explore ideas of mathematics for propagation of knowledge and popularization of mathematics in society.	Ap, E
PSO5	Model the real-world problems into mathematical equations and draw the inferences by finding appropriate solutions.	E, C
PSO6	Comprehend and write effective reports and articles and design documentation related to mathematical research and literature, make effective presentations.	C

Course Structure: Semester-wise distribution of Courses

Semester-I		
Course Code	**Title**	**Credits**
PGMATHCC101	Algebra-I	4
PGMATHCC102	Real Analysis	4
PGMATHCC103	Complex Analysis	4
PGMATHCC104	Ordinary & Partial Differential Equations	4
PGMATHCC105	Numerical Analysis	4
PGMATHCC106	Computer Programming in C++ and Numerical Practical using GNU Octave/Scilab /Matlab	4
Soft Skill-1		
PGMATHSS01	YOGA	1
Semester-II		
PGMATHCC201	Algebra-II	4
PGMATHCC202	Measure and Integration	4
PGMATHCC203	General Topology	4
PGMATHCC204	Classical Mechanics & Theory of Relativity	4
PGMATHCC205	Linear Algebra & Multivariate Calculus	4
PGMATHCC206	Integral transforms and Integral Equations	4
Soft Skill-2		
PGMATHSS02	Communicative English	1
Semester-III		
CC(Core Course)		
PGMATHCC301	Functional Analysis	4
PGMATHCC302	Dynamical System Analysis	4
CE(Core Elective-Any Three)		
PGMATHCE301	Advanced Real Analysis-I	4
PGMATHCE302	Advanced Complex Analysis-I	4
PGMATHCE303	Algebraic Topology-I	4
PGMATHCE304	Differential Manifold-I	4
PGMATHCE305	Cosmology-I	4
PGMATHCE306	Mathematical Biology-I	4
PGMATHCE307	Operation Research-I	4
PGMATHCE308	Continuum Mechanics (Solid)-I	4
Under CBCS a student from our department / Courses will be taught as AE (Allied Elective) by Computer Science Department.		
PGMATHAE301	Programming in PYTHON & LaTex	4
Soft Skill-3		
PGMATHSS03	VE & IC	1
Semester-IV		
CC (Core Course)		

PGMATHCC401	Number theory	4
PGMATHCC402	Discrete Mathematics	4
CE (Core Elective-Any Three)		
PGMATHCE401	Advanced Real Analysis-II	4
PGMATHCE402	Advanced Complex Analysis-II	4
PGMATHCE403	Algebraic Topology-II	4
PGMATHCE404	Differential Manifold-II	4
PGMATHCE405	Cosmology-II	4
PGMATHCE406	Mathematical Biology-II	4
PGMATHCE407	Operation Research-II	4
PGMATHCE408	Continuum Mechanics (Fluid)-II	4
Project Work		
PGMATHCC403	Project Work (Viva Voce + Dissertation)	4
Soft Skill-4		
PGMATHSS04	Seminar Presentation	1
Total Credits (Semester-I+II+III+IV)		**200**

SEMESTER – I
Name of the Course: **ALGEBRA-I**
Course Code: **PGMATHCC101**

Course Objectives (PGMATHCC101)

The prime objectives of the course are:

- To give students a foundation for all future mathematics courses.
- Understand the fundamentals of algebraic problem-solving.
- Explore the foundations of Algebraic structures, Groups, Rings, Ideals, Fields, Homomorphisms, etc.
- To make students aware of the applicability of abstract mathematics in real world problems.

Course Outcomes (PGMATHCC101)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Define algebraic structures	R	PO1	PSO1
CO2	Construct substructures	Ap	PO2, PO3	PSO2
CO3	Analyse a given structure in detail	An	PO1, PO2	PSO3
CO4	Compare structures viz. Groups, rings, fields	E	PO2, PO3	PSO4
CO5	Develop new structures based on given structures	C	PO4	PSO6

SEMESTER – I
Name of the Course: **Real Analysis**
Course Code: **PGMATHCC102**

Course Objectives (PGMATHCC102)

The prime objectives of the course are:

- To provide a deeper and rigorous understanding of fundamental concepts viz. metric spaces, continuous functions, sequences and series of numbers as well as functions, and the Riemann-Stieltjes integral etc.
- To provide a theoretical foundation of the above said concepts and it will cultivate the rigorous mathematical logics and skills in the students.
- To develop the concept of open ball in Euclidean space Rn, covering of a set through open balls and some basic results of metric space, continuity and differentiability in Rn in addition to the concept of bounded variation and its properties.

- To develop the understanding of uniform convergence and Riemann Stieltjes integral and its properties.

Course Outcomes (PGMATHCC102)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Demonstrate an understanding of limits and how that are used in sequences, series and differentiation.	R, U	PO1	PSO1
CO2	Appreciate how abstract ideas and region methods in mathematical analysis can be applied to important practical problems.	U, Ap	PO2, PO3	PSO2
CO3	Describe fundamental properties of the real numbers that lead to the formal development of real analysis.	An	PO1, PO2	PSO3
CO4	Comprehend regions arguments developing the theory underpinning real analysis	E	PO2, PO3	PSO4
CO5	Construct rigorous mathematical proofs of basic results in real analysis.	C	PO3, PO4	PSO5

SEMESTER – I
Name of the Course: **Complex Analysis**
Course Code: **PGMATHCC103**

Course Objectives (PGMATHCC103)

The prime objectives of the course are:

- To introduce and develop a clear understanding of the fundamental concepts of Complex Analysis such as analytic functions, Cauchy-Riemann relations and harmonic functions.
- To enable students to acquire skill of contour integration to evaluate complicated real integrals via residue calculus.
- To provide an introduction to the theories for functions of a complex variable.
- Equip students with the understanding of the fundamental concepts of complex variable theory.

Course Outcomes (PGMATHCC103)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Represent functions as Taylor, power and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem	R, U	PO1	PSO1
CO2	Apply the theory into application of the power series expansion of analytic functions, and understand the	Ap	PO2, PO3	PSO2

	basic methods of complex integration and its application in contour integration			
CO3	Analyse the concept of metric space and some important theorem on complex analysis for solving different problems	An	PO1, PO2	PSO3
CO4	Evaluate complex contour integrals directly and by the fundamental theorem, apply the Cauchy integral theorem in its various versions, and the Cauchy integral Formula	Ap, E	PO2, PO3	PSO4
CO5	Compute Laurent series and its examples, absolute and uniform convergence of power series	C	PO4	PSO6

SEMESTER – I
Name of the Course: **Ordinary and Partial Differential Equations**
Course Code: **PGMATHCC104**

Course Objectives (PGMATHCC104)

The prime objectives of the course are:

- To introduce ordinary differential equations and fundamental theorems for existence and uniqueness.
- Explains the analytic techniques in computing the solutions of various ordinary differential equations appearing in various fields of science and technology.
- To learn quantitative information and qualitative methods which provide a good geometric understanding of ODE.
- Learn to solve boundary value problems including Sturm Liouville Problem and Green's function.
- To learn theory of partial differential equations, solution methods and nature of PDEs like parabolic, elliptic, hyperbolic.

Course Outcomes (PGMATHCC104)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Identify real phenomena as models of partial derivative equations.	U	PO1	PSO1
CO2	Classify differential equations and solve them.	An	PO1, PO2	PSO3
CO3	Apply specific methodologies, techniques and resources to conduct research and produce innovative results in the area of specialisation.	Ap, E	PO2, PO3	PSO4
CO4	Extract information from partial derivative models in order to interpret reality.	E	PO2, PO3	PSO4
CO5	Solve the basic application problems described by differential equations.	E, C	PO3, PO4	PSO5

SEMESTER – I
Name of the Course: **Numerical Analysis**
Course Code: **PGMATHCC105**

Course Objectives (PGMATHCC105)

The prime objectives of the course are:

- To introduce the basic concepts of Numerical Mathematics.
- Learn to solve the problems arising in various fields of application, for example in science, engineering and economics etc. that are difficult to deal with analytically.
- Develop and analyse the application of different numerical methods to solve the problems, viz. system of linear & nonlinear equations, numerical initial and boundary value problems of ordinary differential equations etc.

Course Outcomes (PGMATHCC105)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Understanding the theoretical and practical aspects of the use of numerical analysis.	U	PO1	PSO1
CO2	Understanding of common numerical analysis and how they are used to obtain approximate solutions to otherwise intractable mathematical problems.	R, U	PO1	PSO1
CO 3	Proficiency in implementing numerical methods for a variety of multidisciplinary applications.	R, An	PO1, PO2	PSO3
CO4	Establishing the limitations, advantages, and disadvantages of numerical analysis.	E	PO2, PO3	PSO4
CO5	Deriving numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations and the solution of differential equations.	E, C	PO3, PO4	PSO5

SEMESTER – I
Name of the Course: **Computer Programming in C++ and Numerical Practical using Gnu- Octave / Scilab / Matlab**
Course Code: **PGMATHCC106**

Course Objectives(PGMATHCC106)

The prime objectives of the course are:

- To provide understanding of implementation of basic numerical methods for solving different problems viz. nonlinear equations, system of linear equations, interpolation and extrapolation, numerical differentiation and integration,

numerical initial and boundary value problems of ordinary differential equations etc.

- To develop programming skills in the students in order to write and implement their own computer programs for solving problems arising in science, engineering and economics.
- Learn to develop GNU-OCTAVE/SCILAB/MATLAB programs that perform operations using derived data types.

Course Outcomes (PGMATHCC106)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Reading, understanding and tracing the execution of programs written in C++ language.	R, U	PO1	PSO1
CO2	Solving a linear system of equations using an appropriate numerical method.	Ap	PO2, PO3	PSO2
CO3	Performing an error analysis for a given numerical method.	E, C	PO3, PO4	PSO5
CO4	Developing programs GNU-OCTAVE/SCILAB/MATLAB that perform operations using derived data types.	E, C	PO3, PO4	PSO5
CO5	Solving an algebraic or transcendental equation using an appropriate numerical method.	An, C	PO4	PSO6
CO6	Developing the C++ code for a given algorithm.	C	PO4	PSO6

SEMESTER – II
Name of the Course: **Algebra – II**
Course Code: **PGMATHCC201**

Course Objectives (PGMATHCC201)

The prime objectives of the course are:

- To give students a foundation for advanced study in Algebra.
- Understand the fundamental theorems of algebraic structures.
- Explore the concepts of Polynomial rings, Field extensions, Galois extensions etc.
- Understand to apply the concepts of algebra in real-life situations.

Course Outcomes (PGMATHCC201)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Understand the Matrix theory, determinants and their application to systems of linear Equations	U	PO1	PSO1

CO 2	Apply the knowledge of Eigenvalues, diagonalization of matrices and reduction of systems of linear equations into simpler systems of easily tractable nature.	Ap	PO2, PO3	PSO2
CO3	Apply the concept of Vector theory: subspace, basis, linear independence, inner product spaces etc. in real-world problems	Ap, E	PO2, PO3	PSO4
CO4	Comprehend the applications of matrix algebra.	C, E	PO3, PO4	PSO5

SEMESTER – II
Name of the Course: **Measure and Integration**
Course Code: **PGMATHCC202**

Course Objectives (PGMATHCC202)

The prime objectives of the course are:

- To develop the concept of countable, uncountable sets, Canter set, measurable sets, measurable functions, Lebesgue integral, and the Lebesgue Lp spaces.
- Understand the concept of Lebesgue Lp Spaces, and some important related theorems.
- Teach the concepts of integration of simple functions, Lebesgue integral of a bounded function over a set of finite measures, comparison between- Riemann and Lebesgue integrals.

Course Outcomes (PGMATHCC202)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Conceptualisation of simple functions.	R, U	PO1	PSO1
CO2	Apply the concepts of integration for the study in subsequent chapters namely, signed and product measure.	Ap	PO2, PO3	PSO2
CO3	Generalize the classical Lebesgue integral on real sets.	An, E	PO2, PO3	PSO4
CO4	Integration of functions on arbitrary measure space and bounded functions on sets of finite measure.	C	PO4	PSO6

SEMESTER – II
Name of the Course: **General Topology**
Course Code: **PGMATHCC203**

Course Objectives (PGMATHCC203)

The prime objectives of the course are:

- Introduce the basic definitions and standard examples of topological spaces.
- Illustrate a variety of topological properties such as like compactness, connectedness and separation axioms.
- Explore the idea of topological equivalence and define homeomorphisms.

Course Outcomes (PGMATHCC203)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Define and illustrate the concept of countable set and uncountable set, cardinal numbers and cardinal arithmetic, Zorns lemma and ordinal numbers.	R, U	PO1	PSO1
CO 2	Define and illustrate the concept of topological spaces and continuous functions, product topology and quotient topology, metric topology and Baire category theorem.	R, U	PO1	PSO1
CO3	Define connectedness, compactness, and totally bounded spaces and prove a selection of related theorems.	R, Ap	PO2, PO3	PSO2
CO4	Analyse topological spaces and some important theorem.	An	PO1, PO2	PSO3

SEMESTER – II
Name of the Course: **Classical Mechanics & Theory of Relativity**
Course Code: **PGMATHCC204**

Course Objectives (PGMATHCC204)

The prime objectives of the course are:

- Expose the students to the concept of functional and extremum path and the application of the knowledge in solving some fundamental problems.
- Understand the fundamental concepts in the dynamics of system of particles and Lagrangian and Hamiltonian formulation of mechanics.
- Learn to represent the equations of motion for complicated mechanical systems using the Lagrangian and Hamiltonian formulation of classical mechanics.
- To develop the understanding of moments of inertia and its applications in the dynamics of a rigid body rotating about a fixed point.

- To develop the understanding of the concept of geometrical equations and Lagrange's equations of motion of a rigid body, principles of Hamiltonian, Liouville's Theorem and introduction to Lagrange and Poisson brackets and its applications.

Course Outcomes (PGMATHCC204)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Explain Lagrangian and Hamiltonian formulation of Classical Mechanics.	U	PO1	PSO1
CO 2	State the conservation principles involving momentum, angular momentum and energy and understand that they follow from the fundamental equations of motion.	R, U	PO1	PSO1
CO3	Understand Newton's laws and motion of particle under central force field.	U	PO1	PSO1
CO4	Describe the basic concepts of the theory of relativity.	R, U	PO1	PSO1
CO5	Differentiate facts from wrong general public ideas about the theory of relativity.	An	PO1, PO2	PSO3
CO6	Discuss postulates of the special theory of relativity and their consequences.	R, An	PO1, PO2	PSO3

SEMESTER – II
Name of the Course: **Linear Algebra & Multivariate Calculus**
Course Code: **PGMATHCC205**

Course Objectives(PGMATHCC205)

The prime objectives of the course are:

- Understand the core of linear algebra comprising the theory of linear equations in many variables, the theory of vector spaces and linear maps.
- To introduce some advance material in Linear algebra.
- Visualize the idea of Linear transformations on a finite dimensional inner product space, Riesz representation of the linear functional on inner product space.
- Learn to use the concept of eigenvalues and eigenfunctions.

Course Outcomes (PGMATHCC205)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Characterize a set of vectors and linear systems using the concept of linear independence.	R, U	PO1	PSO1
CO2	Visualize and manipulate multivariable and vector valued functions presented in graphical, numeric, and symbolic form.	An	PO1, PO2	PSO3
CO3	Identify and construct linear transformations of a matrix and characterize them as onto, one-to-one.	E, C	PO3, PO4	PSO5
CO4	Solve linear systems represented as linear transforms and express them in other forms, such as matrix equations and vector equations.	C	PO4	PSO6
CO5	Differentiate multivariate functions in all directions and learn several applications of multivariate derivatives.	C	PO4	PSO6

SEMESTER – II
Name of the Course: **Integral Transforms & Integral Equations**
Course Code: **PGMATHCC206**

Course Objectives (PGMATHCC206)

The prime objectives of the course are:

- Learn to use Fourier Transforms of functions to solve different problems.
- Learn to use Laplace Transforms for solving initial value problem, integral equation, etc.
- Know the types of integral equation and Kernels and relation between integral equation and boundary value problems, green's function.
- Explore the concept of iterated kernels, Neumann series for Volterra integral equation, Abel's integral equation and Cauchy principal for integrals.

Course Outcomes (PGMATHCC206)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understand the Calculus of Variations, Euler-Lagrange's equations.	U	PO1	PSO1
CO2	Obtain solution of a boundary value problem using integral equations.	Ap, E	PO2, PO3	PSO4
CO3	Obtain minimum surface of revolution from a variational formulation.	E	PO2, PO3	PSO4

CO4	Obtain the solution of Wave, Heat and Laplace equations using integral transform technique.	E, C	PO3, PO4	PSO5
CO5	Construct Green's function and master the concept of various Integral Equations: Fredholm and Voltera type.	C	PO4	PSO6

SEMESTER – III
Name of the Course: **Functional Analysis**
Course Code: **PGMATHCC301**

Course Objectives (PGMATHCC301)

- Develop a deeper and rigorous understanding of fundamental concepts of functional analysis, their properties and related theorems.
- Introduce normed spaces, linear operators and derive their properties.
- Elaborate basic theorems like open and closed mapping theorem, implicit function theorem and spectral theorem.
- Understand and learn to work with Fredholm and other integral operator as a linear operator.

Course Outcomes (PGMATHCC301)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Work with a complete orthogonal set in a Hilbert space, weak and weak * topologies on normed linear spaces.	Ap	PO2, PO3	PSO2
CO2	Compare the differences between basis and Schauder basis.	An	PO1, PO2	PSO3
CO3	Investigate the best approximation of a given vector by vectors in given subspace.	An	PO1, PO2	PSO3
CO4	Work with Fredholm and other integral operator as a linear operator.	Ap, E	PO2, PO3	PSO4
CO5	Compute the dual spaces of certain Banach spaces.	C	PO4	PSO6

SEMESTER – III
Name of the Course: **Dynamical System Analysis**
Course Code: **PGMATHCC302**

Course Objectives (PGMATHCC302)

- To develop an understanding of continuous and discrete dynamical systems, Autonomoussystems in $\mathbb{R}^n$, Orbits and Trajectories.
- Explore the linear systems in two and higher dimensions and their stability.

- Learn to work with Bifurcation and Chaos at non-hyperbolic equilibrium points, Saddle-node, Transcritical, Pitchfork and Hopf bifurcations.

Course Outcomes (PGMATHCC302)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Describe the main features of dynamical systems and realise as systems of ordinary differential equations	R, U	PO1	PSO1
CO2	Understand the origin of dissipation and its effect on the orbits of dynamical systems, abstract dynamical system, discrete dynamical system and chaotic dynamical system	U	PO1	PSO1
CO3	Use a range of specialised analytical techniques which are required in the study of dynamical systems	Ap	PO2, PO3	PSO2
CO4	Identify fixed points of simple dynamical systems, and study the local dynamics around these fixed points, in particular to discuss their stability and bifurcations	R, An	PO1, PO2	PSO3
CO5	Explain and prove special properties of finite-dimensional Hamiltonian systems, in particular conservation laws, Liouville's Theorem and Poincare's Recurrence Theorem	E	PO2, PO3	PSO4

SEMESTER – III
Name of the Course: **Advanced Real Analysis**
Course Code: **PGMATHCE301**

Course Objectives (PGMATHCE301)

The prime objectives of the course are:

- Introduce the students to ordinal numbers, their comparability and consequences.
- Learn to use the properties of sets, perfect set, sets of first category and second category, residual sets
- Understand the concepts of Borel sets.
- Learn about functions of some special classes, Banach–Zarecki theorem, Dini's derivates and their simple properties.

Course Outcomes (PGMATHCE301)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understand the concept of extended real numbers, Lebesgue and Borel measures on real line.	R, U	PO1	PSO1
CO2	Understand the measurability of real sets.	U	PO1	PSO1
CO3	Understand the measurability of extended real valued functions.	U	PO1	PSO1
CO4	Solve problems relating to determinations of measures of finite, infinite sets.	Ap, E	PO2, PO3	PSO4
CO5	Construct different Borel sets.	C	PO4	PSO6
CO6	Construct measurable, non-measurable sets and functions.	C	PO4	PSO6

SEMESTER – III
Name of the Course: **Advanced Complex Analysis –I**
Course Code: **PGMATHCE302**

Course Objective (PGMATHCE302)

The prime objectives of the course are:

- Provide the students the basic ideas of infinite products of complex numbers and some associated important theorems.
- Understand the Spherical metrics, Montel's Theorem and Marty's Theorem.
- Exposure to open mapping theorem and Picard's Theorem.

Course Outcomes (PGMATHCE302)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understand Infinite products of complex numbers.	U	PO1	PSO1
CO2	Understand the concept of Spherical metrics, Normal Convergence, Picard's Theorem.	R, U	PO1	PSO1
CO3	Use the Mittag-Leffler Theorem, Gamma functions, Weierstrass' Factorization.	Ap, E	PO2, PO3	PSO4

SEMESTER – III
Name of the Course: **Algebraic Topology-I**
Course Code: **PGMATHCE303**

Course Objectives(PGMATHCE303)

The prime objectives of the course are:

- To provide the knowledge of Topological Spaces and their importance.
- To acquaint students with the concept of Homotopy, Homology and the topological properties.
- To understand the important mathematical concepts which can be generalized in topological spaces, so that students may learn and appreciate the nature of abstract Mathematics.

Course Outcomes (PGMATHCE303)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understanding the fundamental concepts and methods in algebraic topology.	R, U	PO1	PSO1
CO2	Explain particular homotopy and homology theory.	U	PO1	PSO1
CO3	Formulate and solve problems of a geometrical and topological nature in mathematics.	Ap, E	PO2, PO3	PSO4

SEMESTER – III
Name of the Course: **Differential Manifold-I**
Course Code: **PGMATHCE304**

Course Objectives (PGMATHCE304)

The prime objectives of the course are:

- To familiarize students with the detailed knowledge of Surfaces, Geodesic, Geodesic curvature, Gaussian Curvature and Developable Surface.
- Understand the concept of Surface in Space.
- Introduce the concept of Differentiable Manifold, Jacobian Map and parameter group of transformations.

Course Outcomes (PGMATHCE304)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Realize the behaviours of different surfaces, normal curvatures, principle curvatures, Gaussian and mean curvatures.	R, U	PO1	PSO1
CO2	Understand the first and second fundamental forms.	U	PO1	PSO1

CO3	Evaluate 1st and 2nd fundamental forms of surface patches.	E	PO1	PSO1
CO4	Analyse and characterize different curves and surfaces.	R, An	PO1, PO2	PSO3
CO5	Construct differential maps between smooth surfaces.	E, C	PO2, PO3	PSO4

SEMESTER – III
Name of the Course: Cosmology-I
Course Code: **PGMATHCE305**

Course Objectives(PGMATHCE305)

The prime objectives of the course are:

- Familiarise students to our galaxy and the standard model of universe.
- Understand the basics of Tensor Analysis and the General Theory of Relativity.
- Learn the relation between Thermodynamics and cosmology
- Learn to analyze the size, age, structure, and motion of the universe overall.

Course Outcomes(PGMATHCE305)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understanding of our galaxy.	U	PO1	PSO1
CO2	Contrast and compare our galaxy with other galaxies as to type, contents, age, luminosity, motion, and size.	R, An	PO1, PO2	PSO3
CO3	Using cosmological models to analyze the size, age, structure, and motion of the universe overall.	An	PO1, PO2	PSO3

SEMESTER – III
Name of the Course: **Mathematical Biology-I**
Course Code: **PGMATHCE306**

Course Objectives (PGMATHCE306)

The prime objectives of the course are:

- Aware the students about the effect of nutrients on autotrophy-herbivore interaction.
- Introduce to the dynamics of Phytoplankton-Zooplankton system.
- Understand the Microbial population model and other Mathematical models in ecology.

Course Outcomes (PGMATHCE306)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Use sophisticated mathematical techniques in the analysis of mathematical models in biology.	Ap	PO2, PO3	PSO2
CO2	Apply and extend classical models in mathematical biology.	Ap, E	PO2, PO3	PSO4
CO3	Construct mathematical models for biological systems like phytoplankton-zooplankton system, Microbial population model, Discrete and Continuous population models.	C	PO4	PSO6

SEMESTER – III
Name of the Course: **Operation Research-I**
Course Code: **PGMATHCE307**

Course Objectives (PGMATHCE307)

The prime objectives of the course are:

- To introduce basic optimization techniques in order to get best results from a set of several possible solutions of different problems.
- Learn to formulate of real world phenomena from its physical considerations and implementation of optimization algorithms for solving these problems.
- Learn to solve linear programming problems, transportation problem, assignment problem and unconstrained and constrained problems etc.
- Acquaint students to deal with non-linear programmings.

Course Outcomes (PGMATHCE307)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Show the Kuhn-Tucker optimality conditions.	U	PO1	PSO1
CO2	Formulate and solve problems as networks and graphs.	E, C	PO3, PO4	PSO5
CO3	Construct linear integer programming models and discuss the solution techniques.	An, C	PO4	PSO6
CO4	Develop linear programming (LP) models for shortest path, maximum flow, minimal spanning tree, critical path, minimum cost flow, and transhipment problems.	C	PO4	PSO6
CO5	Solve the problems using special solution algorithms.	C	PO4	PSO6

SEMESTER – III
Name of the Course: **Continuum Mechanics-I**
Course Code: **PGMATHCE308**

Course Objectives (PGMATHCE308)

The prime objectives of the course are:

- To provide a treatment of advanced topics in solid mechanics.
- Learn to apply the techniques of continuum mechanics in deriving important results and in research problems.
- To provide the student with knowledge of the elastostatics and elastodynamics and an appreciation of their application to real world problems.

Course Outcomes (PGMATHCE308)

After completing the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Describe motion, deformation and forces in a continuum.	U	PO1	PSO1
CO2	Understand constitutive models for elastic and viscoelastic solids.	R, U	PO1	PSO1
CO3	Derive equations of motion and conservation laws for a continuum.	Ap	PO2, PO3	PSO2
CO4	Solve simple boundary value problems for solids.	Ap, E	PO2, PO3	PSO4

SEMESTER – III
Name of the Course: **Programming in Python & LaTex**
Course Code: **PGMATHAE301**

Course Objectives (PGMATHAE301)

The prime objectives of the course are:

- To develop Python and Latex programming for solving real world problems.
- Learn to use mathematical tools on Python.
- Develop codes for basic functions, animation, matplot, Rolle's and Mean value theorems.
- Learn to work on large projects using programming in Python and LaTex.

Course Outcomes (PGMATHAE301)

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

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Understand the fundamentals of Python Language and the basics of LaTeX.	R, U	PO1	PSO1
CO 2	Acquire the basic skills required for Python programming.	U	PO1	PSO1
CO 3	Solve Mathematical problems using Python programs.	Ap	PO2, PO3	PSO2
CO 4	Learn to prepare a LaTeX document, article and a project report.	Ap, E	PO2, PO3	PSO4

SEMESTER – IV
Name of the Course: **Number Theory**
Course Code: **PGMATHCC401**

Course Objectives (PGMATHCC401)

The prime objectives of the course are:

- Understand the concept of Partitions and Compositions.
- Introduce the Euler's Generalization of Fermat's Theorem.
- Understand the primitive roots, indices and the quadratic reciprocity law
- Expose to the concept of the Arithmetic of *Zp,* pseudo prime, Carmichael Numbers, Quadratic residues and non quadratic residues.

Course Outcomes (PGMATHCC401)

Upon completion of the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Use congruence as a tool to reduce a hard labour of work in some calculations.	Ap	PO1	PSO1
CO2	Find primitive roots.	R	PO1	PSO1
CO3	Establish existing identities using Mobius inversion formula.	An	PO1, PO2	PSO3
CO4	Solve a Diophantine equation and system of Diophantine equations.	E, C	PO3, PO4	PSO5

SEMESTER – IV
Name of the Course: **Discrete Mathematics**
Course Code: **PGMATHCC402**

Course Objectives (PGMATHCC402)

The prime objectives of the course are:

- Prepare students to develop mathematical foundations to understand and create mathematical arguments require in learning many mathematics and computer sciences courses.
- To motivate students how to solve practical problems using discrete mathematics.
- Introduce the basic concepts of Graph theory such as Trees, Eulerian Graphs, Matching, Vertex colourings, Edge colourings, Planarity.

Course Outcomes (PGMATHCC402)

After completing the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Understand the basic combinatorics, induction, inclusion exclusion, pigeon-hole principle.	U	PO1	PSO1
CO 2	Understand more advance topics in combinatorics: recurrence relations, generating functions.	R, U	PO1	PSO1
CO 3	Understand the basic logical concepts, analyzing arguments, quantification theory.	U	PO1	PSO1
CO 4	Apply the concepts to real life problems such as network theory, data structure, optimization etc.	Ap	PO2, PO3	PSO2
CO 5	Construct the method of deduction for validity of truth.	Ap	PO2, PO3	PSO2

SEMESTER – IV
Name of the Course: **Advanced Real Analysis -II**
Course Code: **PGMATHCE401**

Course Objectives (PGMATHCE401)

The prime objectives of the course are:

- To consider theoretical foundations of concepts of mathematical analysis, viz. derivative, MVTs, functions of several variables, measure theory and integration.
- Learn to use the important applications of the subject in different branches of pure and applied mathematics.
- Enable students familiar with the concepts of real analysis and their fruitful applications.
- Understand the concept of measurable sets, non-measurable sets and Borel sets.

Course Outcomes (PGMATHCE401)

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

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Solve problems relating to determinations of measures of finite, infinite sets.	Ap, E	PO2, PO3	PSO4
CO2	Constructing measurable, non-measurable sets and functions.	E, C	PO3, PO4	PSO5
CO3	Construct different Borel sets.	C	PO4	PSO6

SEMESTER – IV
Name of the Course: **Advanced Complex Analysis-II**
Course Code: **PGMATHCE402**

Course Objectives(PGMATHCE402)

The prime objectives of the course are:

- Understand the concept of order and genus of entire functions.
- Learn to use the Poisson's integral formula and Meromorphic functions.
- Familiarise the univalent functions, Area theorem and Distortions theorem.

Course Outcomes (PGMATHCE402)

After completing the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO 1	Classify singularities, Integration of functions on C, applications to counting zeros and poles.	U	PO1	PSO1
CO 2	Evaluate definite real integrals.	E	PO2, PO3	PSO4
CO 3	Construct Mobius transformation between regions.	Ap, E	PO2, PO3	PSO4

SEMESTER – IV
Name of the Course: **Algebraic Topology – II**
Course Code: **PGMATHCE403**

Course Objectives (PGMATHCE403)

The prime objectives of the course are:

- Learn to prove and use the concepts of algebraic topology.
- Understand the cellular homology of a CW complex, Kunneth theorem and Eilenberg- Zilber Theorem.
- Perform mathematical reasoning with advanced knowledge of topology viz. higher homotopy groups, Whitehead's theorem, Cellular approximation and CW approximation.

Course Outcomes (PGMATHCE403)

Upon successful completion, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Explain the fundamental concepts of algebraic topology and their role in modern mathematics and applied contexts.	R, U	PO1	PSO1
CO2	Apply problem-solving using algebraic topology techniques applied to diverse situations in physics, engineering and other mathematical contexts.	Ap	PO2, PO3	PSO2
CO3	Demonstrate accurate and efficient use of algebraic topology techniques.	Ap, An	PO1, PO2	PSO3
CO4	Demonstrate capacity for mathematical reasoning through analyzing, proving and explaining concepts from algebraic topology.	Ap, An	PO1, PO2	PSO3

SEMESTER – IV
Name of the Course: **Differential Manifold-II**
Course Code: **PGMATHCE404**

Course Outcomes (PGMATHCE404)

The prime objectives of the course are:

- Introduce differentiable manifolds from an intrinsic point of view, leading to classical theorems such as the generalised Stokes theorem.
- Realise the subject matter of Lie algebra of vector fields on a manifold, Lie derivative of vector fields, Lie derivatives of differential forms, Frobenius theorem.
- Provides the necessary concepts to start studying more advanced areas of geometry, topology, analysis and mathematical physics.

Course Outcomes (PGMATHCE404)

After completing the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addresse
CO1	Understand the normal curvature of a surface, its connection with the first and second fundamental form and Euler's theorem.	R, U	PO1	PSO1
CO2	Understand the concept of topological manifolds.	U	PO1	PSO1
CO3	Understand the concept of Lie group.	U	PO1	PSO1
CO4	Solve problems using Stoke's theorem, line integral and Green's theorem.	Ap	PO2, PO3	PSO2

SEMESTER – IV
Name of the Course: **Cosmology-II**
Course Code: **PGMATHCE405**

Course Objectives (PGMATHCE405)

The prime objectives of the course are:

- Know the history of our universe from the Big Bang, through the formation of the cosmic microwave background; to the universe we see today, with all its large scale structures.
- Understand this whole evolution, perturbation theory, Einstein's General Theory of Relativity, statistical physics, thermodynamics, and a little bit of quantum field theory.
- Learn the theory, then implement and numerically solve the equations derived in order to obtain theoretical predictions.
- Learn to analyse the size, age, structure and motion of the universe overall.

Course Outcomes (PGMATHCE405)

After completing the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understand the concept of advanced cosmology.	U	PO1	PSO1
CO2	Use an understanding of our galaxy to contrast and compare it with other galaxies as to type, contents, age, luminosity, motion, and size.	Ap	PO2, PO3	PSO2
CO3	Use cosmological models to analyze the size, age, structure, and motion of the universe overall.	R, An	PO1, PO2	PSO3

SEMESTER – IV
Name of the Course: **Mathematical Biology-II**
Course Code: **PGMATHCE406**

Course Objectives (PGMATHCE406)

The prime objectives of the course are:

- Introduce students to the application of mathematical modeling in the analysis of biological systems including populations of molecules, cells and organisms.
- To show how mathematics, statistics and computing can be used in an integrated way to analyse biological systems.
- To develop students' skills in algebraic manipulation, the calculus of linear and non-linear differential equations, mathematical modelling, matrix algebra and statistical methods.
- To introduce students to the use of R for the analysis of biological processes and data, including simple computer programming.

Course Outcomes (PGMATHCE406)

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

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Apply and extend classical models in mathematical biology.	Ap	PO2, PO3	PSO2
CO2	Construct mathematical models for biological systems like Continuous models for two, three or more interacting populations, Interaction of Ratio-dependent models.	Ap	PO2, PO3	PSO2
CO3	Use sophisticated mathematical techniques in the analysis of mathematical models in biology.	Ap, E	PO2, PO3	PSO4

SEMESTER – IV
Name of the Course: **Operations Research-II**
Course Code: **PGMATHCE407**

Course Objectives(PGMATHCE407)

The prime objectives of the course are:

- Learn to formulate and solve problems as networks and graphs.
- Develop linear programming (LP) models for shortest path, maximum flow, minimal spanning tree, critical path, minimum cost flow, and transshipment problems.
- Learn to solve the problems using special solution algorithms.
- Explore the information theory, queuing theory and the theory of inventory control.

Course Outcomes (PGMATHCE407)

On completion of this course, students should be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Define and formulate linear programming problems and solve them using appropriate techniques and optimization solvers, interpret the results obtained and translate solutions into directives for action.	R, U	PO1	PSO1
CO2	Understand the concept of Queuing theory, simulation, Theory of Inventory Control, Information theory, Coding theory and Geometric Programming.	R, U	PO1	PSO1
CO3	Conduct and interpret post-optimal and sensitivity analysis and explain the primal-dual relationship.	U	PO1	PSO1
CO4	Develop mathematical skills to analyse and solve integer programming and network models arising from a wide range of applications.	Ap	PO2, PO3	PSO2
CO5	Effectively communicate ideas, explain procedures and interpret results and solutions in written and electronic forms to different audiences.	Ap, E	PO2, PO3	PSO4

SEMESTER – IV
Name of the Course: **Continuum Mechanics-II**
Course Code: **PGMATHCE408**

Course Objectives(PGMATHCE408)

The prime objectives of the course are:

- To expose the students to the basic elements of continuum mechanics in a sufficiently rigorous manner.
- To appreciate a wide variety of advanced courses in fluid mechanics.
- Understanding the behaviour of viscous fluid dynamics.
- To analyze the problems related to basic incompressible viscous flows and non-dimension parameters for a given system.

Course Outcomes (PGMATHCE408)

After completing the course, students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Describe the physical properties of a fluid.	U	PO2, PO3	PSO2
CO2	Demonstrate the application point of hydrostatic forces on plane and curved surfaces.	R, U	PO2, PO3	PSO4
CO3	Calculate the pressure distribution for incompressible fluids.	E	PO2, PO3	PSO4
CO4	Calculate the hydrostatic pressure and force on plane and curved surfaces.	E, C	PO3, PO4	PSO5

SEMESTER – IV
Name of the Course: **Project Work**
Course Code: **PGMATHCC403**

Course Objectives (PGMATHCC403)

The prime objectives of the course are:

- Learn to apply fundamental and disciplinary concepts and methods in ways appropriate to their principal areas of study.
- Demonstrate skill and knowledge of current information and technological tools and techniques specific to the professional field of study.
- Use effectively oral, written and visual communication.
- Learn to identify, analyze, and solve problems creatively through sustained critical investigation.
- Learn to integrate information from multiple sources.

Course Outcomes (PGMATHCC403)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Demonstrate a sound technical knowledge of their selected project topic.	U	PO1	PSO1
CO2	Design engineering solutions to complex problems utilising a systems approach.	Ap	PO2, PO3	PSO2
CO3	Undertake problem identification, formulation and solution.	An	PO1, PO2	PSO3
CO4	Conduct an engineering project.	Ap, E	PO2, PO3	PSO4

SEMESTER – IV
Name of the Course: **Seminar Presentation**
Course Code: **PGMATHSS04**

Course Objectives (PGMATHSS04)

The prime objectives of the course are:

- To show competence in identifying relevant information, defining and explaining topics under discussion.
- Learn to judge when to speak and how much to say, speak clearly and audibly in a manner appropriate to the subject, ask appropriate questions, use evidence to support claims, respond to a range of questions.
- Make the students able to take part in meaningful discussion to reach a shared understanding.
- Learn to show their depth of understanding and intellectual leadership and effective time management.

Course Outcomes (PGMATHSS04)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Show competence in identifying relevant information, defining and explaining topics under discussion.	R, U	PO1	PSO1
CO2	Demonstrate depth of understanding, use primary and secondary sources.	Ap	PO2, PO3	PSO2
CO3	Demonstrate complexity, insight, cogency, independent thought, relevance, and persuasiveness.	Ap	PO2, PO3	PSO2
CO4	Evaluate information and use and apply relevant theories.	Ap, E	PO2, PO3	PSO4

RAMAKRISHNA MISSION VIVEKANANDA CENTENARY COLLEGE

RAHARA, KOLKATA-700118

DEPARTMENT OF MATHEMATICS

SESSION 2019-20

Programme Outcomes, Programme Specific Outcomes, Course Objectives and Course Outcomes of Syllabus for Ph.D. in Mathematics

Principal
Ramakrishna Mission
Vivekananda Centenary College
Rahara, Kolkata-700 118

PROGRAM OUTCOMES

After completion of the Ph.D. Degree program, the students will be able to

PO No.	Program Outcomes	Cognitive Level
PO 1	Understands and apply theories, methodologies, and knowledge to address fundamental questions in their primary area of study.	U, Ap
PO 2	Demonstrate the gained knowledge and skills in oral and written and hence communicate them to publish and present work in their field.	E, C
PO 3	Develop a mastery of analysing skills and knowledge at a level required for college and university undergraduate teaching in their discipline and assessment of student learning.	An
PO 4	Develop the intellectual independence that epitomizes true scholarship and Pursue research of significance in the discipline under the guidance of an advisor.	C

R= remembering, U = understanding, Ap = applying, An = analysing, E = evaluating, and C = creating

PROGRAMME SPECIFIC OUTCOMES

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

PSO No.	Program Specific Outcomes	Cognitive Level
PSO1	Mastery of fundamental knowledge in Mathematics (Algebra, Analysis, Geometry).	U, Ap
PSO2	Ability to solve problems and communicate solutions in rigorous mathematical language.	E, C
PSO3	Ability to communicate mathematical concepts effectively.	An, C
PSO4	Ability to conduct independent research.	C

R= remembering, U = understanding, Ap = applying, An = analysing, E = evaluating, and C = creating

Course Structure

Course Code	Course Title	Credit
PHDMATH01	Research Methodology	4
PHDMATH02	Computer Applications	4
PHDMATH03	Literature review	4
	Special Paper	
PHDMATH04	Algebraic Topology	4
PHDMATH05	Complex Analysis	4
PHDMATH06	Cosmology	4
Total Credits		16

SEMESTER – I	
Name of the Course: **Research Methodology**	
Course Code: **PHDMATH01**	
Full Marks: 100	Credit: 4
Number of classes required: 60	
This course has been newly introduced vide BOS meeting dated 26/02/2019	

Course Objectives (PHDMATH01)

The prime objectives of the course are:

- Develop the ability to choose methods appropriate to research aims and objectives.
- Understand the advantages and disadvantages of particular research method.
- Develop skill of critical thinking and the skill of qualitative and quantitative data analysis and presentation.
- Prepare students for organizing and conducting research in a more appropriate manner

Course Outcomes (PHDMATH01)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understand the objectives, motivation and types of research	U	PO1	PSO1
CO2	Define and formulate a research problem	R, C	PO4	PSO2
CO3	Collect data (primary or secondary) based on the formulated problem and analyse the data.	An	PO2	PSO3
CO4	Analyse the data with hypothesis testing, generalization and interpretation.	An, C	PO3	PSO3
CO5	Discuss the application of results and write the thesis.	Ap, E	PO3	PSO4

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SEMESTER – I	
Name of the Course: **Computer Applications**	
Course Code: **PHDMATH02**	
Full Marks: 100	Credit: 4
Number of classes required: 60	
This course has been newly introduced vide BOS meeting dated 26/02/2019	

Course Objectives (PHDMATH02)

The prime objectives of the course are:

- To develop competency in technical writing.
- To master the fundamentals of writing LaTeX and Python scripts.
- To acquire Object Oriented Skills in Python.
- To develop the skill of designing Graphical user Interfaces in Python and LaTeX.
- To develop the ability to write database applications in Python.

Course Outcomes (PHDMATH02)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Explain and use TeX and LaTeX.	An	PO2	PSO2
CO2	Understand the advantages of LaTeX over other more traditional software's.	U	PO1	PSO1
CO3	Prepare handouts and presentations using LaTeX.	C	PO4	PSO3
CO4	Understand the core Python scripting elements such as variables and flow control structures.	U, Ap	PO1	PSO1
CO5	Use Python to read, write, demonstrations files.	E, C	PO3	PSO3

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SEMESTER – I	
Name of the Course: **Literature review**	
Course Code: **PHDMATH03**	
Full Marks: 100	Credit: 4
Number of classes required: 60	
This course has been newly introduced vide BOS meeting dated 26/02/2019	

Course Objectives (PHDMATH03)

The prime objectives of the course are:

- To learn to review and assess scientific literature critically.
- To write and present an overview of the relevant literature for a specific research topic.
- To develop knowledge, insight, and academic skills.
- To develop transferable skills & interpersonal skills.

Course Outcomes

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Identify and retrieve relevant publications within a field of research and write a literature review by searching the literature systematically.	An, E	PO2	PSO4

CO2	Select representative scientific sources from several perspectives relevant to the assignment.	E	PO2	PSO3
CO3	Write a research proposal for obtaining Financial assistance from national funding agencies.	C	PO4	PSO4
CO4	Draw conclusions related to the research problem and give recommendations towards new research opportunities.	C	PO4	PSO4
CO 5	Represent and systematically structure a discussion on the theories and experimental results and define, design and write a literature review independently	An, C	PO3	PSO2

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SEMESTER – I	
Name of the Course: **ALGEBRAIC TOPOLOGY**	
Course Code: **PHDMATH04**	
Full Marks: 100	Credit: 4
Number of classes required: 60	
This course has been newly introduced vide BOS meeting dated 26/02/2019	

Course Objectives (PHDMATH04)

The prime objectives of the course are:

- To provide the knowledge of Topological Spaces and their importance.
- To acquaint students with the concept of Homotopy, Homology and the topological properties.
- To understand the important mathematical concepts which can be generalized in topological spaces, so that students may learn and appreciate the nature of abstract Mathematics.

Course Outcomes(PHDMATH04)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understanding the fundamental concepts and methods in algebraic topology.	R, U	PO1	PSO1
CO2	Explain particular homotopy and homology theory.	U	PO1	PSO1
CO3	Formulate and solve problems of a geometrical and topological nature in mathematics.	Ap, E	PO2	PSO2
CO4	Apply problem-solving using algebraic topology techniques and theorems including the Fundamental theorem of Algebra, Separation Theorem in the plane, Selfert – van Kampen Theorem.	Ap	PO1	PSO1

SEMESTER – I	
Name of the Course: **COMPLEX ANALYSIS**	
Course Code: **PHDMATH05**	
Full Marks: 100	Credit: 4
Number of classes required: 60	
This course has been newly introduced vide BOS meeting dated 26/02/2019	

Course Objectives (PHDMATH05)

The prime objectives of the course are:

- Provide the students the basic ideas of infinite products of complex numbers and some associated important theorems.
- Understand the Spherical metrics, Montel's Theorem and Marty's Theorem.
- Exposure to open mapping theorem and Picard's Theorem.
- Learn to use the Poisson's integral formula and Meromorphic functions.
- Familiarise the univalent functions, Area theorem and Distortions theorem.

Course Outcomes(PHDMATH05)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understand Infinite products of complex numbers.	U	PO1	PSO1
CO2	Understand the concept of Spherical metrics, Normal Convergence, Picard's Theorem.	R, U	PO1	PSO1
CO3	Use the Mittag-Leffler Theorem, Gamma functions, Weierstrass' Factorization.	Ap, E	PO1	PSO1
CO 4	Classify singularities, Integration of functions on C, applications to counting zeros and poles.	U	PO1	PSO1
CO 5	Evaluate definite real integrals.	E	PO2	PSO2
CO 6	Construct Mobius transformation between regions.	Ap, E	PO2	PSO2

SEMESTER – I	
Name of the Course: **COSMOLOGY**	
Course Code: **PHDMATH06**	
Full Marks: 100	Credit: 4
Number of classes required: 60	
This course has been newly introduced vide BOS meeting dated 26/02/2019	

Course Objectives (PHDMATH06)

The prime objectives of the course are:

- Familiarise students to our galaxy and the standard model of universe.
- Understand the basics of Tensor Analysis and the General Theory of Relativity.
- Learn the relation between Thermodynamics and cosmology
- Learn to analyze the size, age, structure, and motion of the universe overall.

Course Outcomes(PHDMATH06)

On successful completion of the course students will be able to:

CO. No.	Course Outcome	Cognitive Level	POs Addressed	PSOs Addressed
CO1	Understanding of our galaxy.	U	PO1	PSO1
CO2	Contrast and compare our galaxy with other galaxies as to type, contents, age, luminosity, motion, and size.	R, An	PO3	PSO3
CO3	Using cosmological models to analyze the size, age, structure, and motion of the universe overall.	An	PO3	PSO3