SIKKIM UNIVERSITY

(A Central University Established by an Act of Parliament of India, 2007)

LEARNING OUTCOME - BASED CURRICULUM

M.SC. IN MATHEMATICS

(With effect from Academic Session 2023-24)

DEPARTMENT OF MATHEMATICS

SIKKIM UNIVERISTY

6TH MILE, TADONG - 737102

GANGTOK, SIKKIM, INDIA

VICE-CHANCELLOR'S MESSAGE

Sikkim University stands at the forefront of embracing the transformative National Education Policy (NEP) 2020. In alignment with NEP 2020's vision and the guidelines of the Learning Outcomes-based Curriculum Framework (LOCF) mandated by the UGC, we have undertaken a comprehensive revision of our curriculum across all departments. This initiative ensures a holistic educational experience that transcends traditional knowledge delivery, emphasizing the practical application of knowledge in real-world scenarios.The shift towards LOCF marks a pivotal change from teacher-centric to learner-centric education, fostering a more active and participatory approach to learning. Our updated curriculum clearly defines Graduate Attributes, Programme Learning Outcomes (PLOs), and Course Learning Outcomes (CLOs), setting clear objectives for our students to achieve. This revision is designed to enable a teaching-learning environment that supports the attainment of these outcomes, with integrated assessment methods to monitor and encourage student progress comprehensively.

A key innovation in our curriculum is the mandatory integration of Massive Open Online Courses (MOOCs) through the SWAYAM platform, enhancing accessibility and the breadth of learning opportunities for students. Our approach encourages multidisciplinary studies through the curriculum while allowing for specialization. The curriculum embodies the policy's core principle of flexibility by enabling mobility for students, thereby allowing the exit and entry of students in the program.

I extend my heartfelt gratitude to our faculty, the Head of the Department, the Curriculum Development Committee members, the NEP coordinators, and the dedicated NEP Committee of Sikkim University for their relentless dedication to updating our curriculum. I appreciate Prof. Yodida Bhutia, the Chairperson, and all dedicated NEP Committee members for their thorough review and integration of LOCF and NEP components into our curriculum.

To our students, I convey my best wishes as we embark on this journey with our updated and inclusive curriculum, aiming not only to enrich their academic knowledge but also to nurture their personal growth, critical thinking, and ability to adapt and innovate in an ever-changing world.

Best wishes,

Prof. Avinash Khare
Vice Chancellor
Sikkim University

Preamble

The Master of Science (MSc) in Mathematics at Sikkim University aims to provide students rigorous knowledge and skills in mathematics as per National Education Policy (NEP 2020) curriculum framework. The program is designed to equip students with a solid foundation in core mathematical subjects, as well as specialized knowledge in specific areas of mathematics. The program also emphasizes the development of critical thinking, problem-solving, and research skills. The MSc Mathematics program covers a range of topics in both pure and applied mathematics that benefit students to tailor their education to their interests and career goals. Students can choose from a range of electives in different and/or related areas of mathematics. The program also includes a research component, where students work on a research project under the supervision of a faculty member. Upon completion of the MSc Mathematics program, students will be equipped with knowledge and skills in mathematics, as well as the ability to apply this knowledge to solve complex problems in various fields. Graduates of the program are well-prepared for further studies in mathematics or related fields, or for careers in academia, industry, or government.

Post Graduate Attributes

PGA1 Broad foundational courses: Two-year MSc mathematics curriculum includes a range of foundational courses covering topics such as linear algebra, abstract algebra, real and functional analysis, complex analysis, topology, and differential equations. These courses provide a solid theoretical background for further specialization.

PGA2 Specialization options: The curriculum offers a variety of specialization options within the MSc mathematics program, allowing students to focus on areas such as algebraic geometry, algebraic topology, graph theory, dynamical systems, mathematical modelling, mathematical biology, and data modelling and interpretations. Students can choose electives based on their interests and career goals.

PGA3 Advanced coursework: The curriculum includes advanced coursework that delves deeper into specific mathematical concepts and techniques. These courses may cover topics like functional analysis, topology, differential geometry, partial differential equations, numerical analysis, probability theory, and mathematical statistics.

PGA4 Research component: MSc mathematics programme includes a research component, where students are required to undertake a research project or write a thesis under the guidance of a faculty member. This component allows students to develop their research skills and explore a specific area of mathematics in depth.

PGA5 Seminar series and presentations: To foster intellectual exchange and enhance communication skills, department organizes seminar series where students and faculty members present their research work or discuss interesting mathematical topics. Participation in such seminars and presentations may be a requirement or encouraged as part of the MSc curriculum.

Program Learning Outcomes

PLO1 Comprehensive mathematical knowledge: Students should develop a good understanding of mathematical concepts and techniques and should be able to apply this knowledge to solve complex problems in mathematics and related fields.

PLO2 Research skills: The MSc Mathematics program should equip students with the research skills necessary to undertake independent research projects. This includes developing research questions, designing experiments or simulations, analysing data, and presenting results.

PLO3 Critical thinking and problem-solving abilities: Through assignments, projects, group discussions students should develop critical thinking and problem-solving abilities. They should be able to analyse problems, develop hypotheses, and design experiments to test those hypotheses.

PLO4 Communication skills: Students should develop strong communication skills through presentations, writing proposals and reports, and cooperating with others. This includes the ability to present complex mathematical concepts to both technical and non-technical audiences.

PLO5 Preparation for further study or employment: The MSc Mathematics program should prepare students for further study at the PhD level, or for employment in industry or academia. Graduates should be able to apply their mathematical knowledge and research skills in a wide range of contexts, from finance and engineering to computer science and data analysis.

Programme Structure

Total Credits: 86

Structure of the curriculum

Sr. No.	Course category	Number of courses	Credits per course	Total credits
I	C: Core courses	8	4	32
II	E: Elective courses*	5	4	20
III	O: Open elective	2	4	08
IV	V: Value Added Course**	2	4+2	06
IV	S: Skill enhancement courses	4	2	08
V	R: Projects***	1	8	08
VI	P: Labs	2	2	04
Total credits				**86**

***Some elective courses, open elective and/or skill enhancement courses may be offered from SWAYAM platform (up to 40% of the total syllabus) depending on student's interest and departmental recommendations and the courses can be completed anytime during the M.Sc programme.**

****Cyber Security and Indian Contributions to Mathematics will be offered as Value Added Courses**

*****Project work should be started 3rd semester onwards with the internal credit allocation of 4 that will be add-on in the final semester, and the rest of 4 credit will be allocated in the final semester; it can be carried out under the supervision of external expert if desired with the approval of the Department.**

Semester-wise course distributions

(With the fixed course credit, L/T/P ratio may vary depending on the course contents)

Course title	Course code	Lecture (L)	Tutorial (T)	Practical (P)	Credits	Total Marks	IA	EA
SEMESTER-I								
Analysis	MTH-C-501	3	1	0	4	100	50	50
Linear Algebra	MTH-C-502	3	1	0	4	100	50	50
Differential Equations	MTH-C-503	3	1	0	4	100	50	50
Algebra-I	MTH-C-504	3	1	0	4	100	50	50
Indian Contributions to Mathematics	MTH-V-505	3	1	0	4	100	50	50
Mathematical Reasoning	MTH-S-506	1	1	0	2	50	25	25
FIRST SEMESTER TOTAL					22	550	275	275
SEMESTER-II								
Complex Analysis	MTH-C-551	3	1	0	4	100	50	50
Algebra-II	MTH-C-552	3	1	0	4	100	50	50
Topology	MTH-C-553	3	1	0	4	100	50	50
Open Elective-A/ Open Elective-B	Any courses from MTH-O-554 to MTH-O-555 or from any other dept.	3	1	0	4	100	50	50
Scientific Computing	MTH-S-556	1	0	1	2	50	50	-
Cyber Security	MTH-V-557	1	1	0	2	50	25	25
Coding Lab	MTH-P-558	0	0	2	2	50	50	-
SECOND SEMESTER TOTAL					22	550	325	225
SEMESTER-III								
Functional Analysis	MTH-C-601	3	1	0	4	100	50	50
Open Elective-A/ Open Elective-B	Any courses from MTH-O-602 to MTH-O-603 or from any other dept.	3	1	0	4	100	50	50
Elective-A /Elective-B	Any courses from MTH-E-604 to MTH-E-608	3	1	0	4	100	50	50
Elective-A/ Elective-B	Any courses from MTH-E-604 to MTH-E-608	3	1	0	4	100	50	50
Data Analysis	MTH-S-609	1	0	1	2	50	50	-
Mathematical software	MTH-P-610	0	0	2	2	50	50	-
THIRD SEMESTER TOTAL					20	500	300	200
SEMESTER-IV								
Elective A/Elective B	Any courses from MTH-E-651 to MTH-E-656	3	1	0	4	100	50	50
Elective A/Elective B	Any courses from MTH-E-651 to MTH-E-656	3	1	0	4	100	50	50
Elective A/Elective B	Any courses from MTH-E-651 to MTH-E-656	3	1	0	4	100	50	50
Modelling and Machine Learning	MTH-S-657	1	0	1	2	50	50	-
Projects/Dissertation	MTH-R-658	0	0	0	8	200	200	-
FOURTH SEMESTER TOTAL					22	550	400	150

List of elective/open elective courses for Semester-II, III, and IV

(Some elective papers will be offered as open electives considering interest and need of students from other departments and interdisciplinary interests of faculty members)

Open Elective Course Name	**Course Code**
Numerical Methods	MTH-O-554
Optimization Techniques	MTH-O-555
Matrix Analysis	MTH-O-602
Discrete Mathematics	MTH-O-603
Elective Course Name	**Course Code**
Measure Theory	MTH-E-604
Algebraic Topology	MTH-E-605
Differentiable Manifolds	MTH-E-606
Field Theory	MTH-E-607
Dynamical Systems	MTH-E-608
Commutative Algebra	MTH-E-651
Graph Theory	MTH-E-652
Mathematical Biology	MTH-E-653
Stochastic Processes	MTH-E-654
Curves and Surfaces	MTH-E-655
Algebraic Geometry	MTH-E-656

Detailed Syllabus
Semester-I

Name of the Programme: M.Sc.
Course Code: MTH-C-501
Name of the Course: Analysis

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 Hrs	60 Hrs

Course Learning Outcomes (CLOs)	1. Students will be able to take more advanced courses in analysis. 2. students will have a solid foundation for other courses in mathematics. 3. Students will have a solid analytical ability. 4. Students will be able to apply the knowledge across disciplines.

Unit	**Unit Title**	**Contents**
I	Real Number system and metric Spaces	Review of axioms of real number system and basic results, metric Spaces, open and closed sets, limit points, interior points, compact sets, nested interval theorem, Heine-Borel theorem, and Bolzano-Weierstrass' threorem, limits and continuity of functions between metric spaces, uniform continuity, connected sets, connected subsets of real numbers
II	Sequence and Series	Review of sequences and series of numbers and basic results, sequences of functions, pointwise and uniform convergence, uniform convergence and continuity, uniform convergence and integration, uniform convergence and differentiation, Weierstrass'approximation theorem.
III	Differentiability of Functions of Several Variables in metric spaces	Review of differentiation of one variable functions and basic results, directional derivatives and differentiability of functions of several variables, chain rule; higher order partial derivatives, equality of mixed partial derivatives, Taylor's theorem, inverse and implicit function theorems, extremum problems with constraints.
IV	Riemann Integrals and multiple Integrals	Review of Riemann integrals, fundamental theorem of calculus, multiple integrals, repeated integrals, interchange of order of integrations, change of variable theorem, mean-value theorems for multiple integrals, line integral and Green's, theorem, Soke's theorem, Gauss' divergence theorem.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate any)*

- Problem solving.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Terence Tao (2016) Analysis I and Analysis II (3rd Edition), Hindustan Book Agency
- Bartle, R.G. (1994) The Elements of Real Analysis (3rd edition), Wiley International
- Rudin, W. (2013) *Principles of Mathematical Analysis* (3rd Edition), Tata McGraw Hill Education.
- Apostol, Tom M. (2000) *Mathematical Analysis* (2nd edition) Narosa Book Distributers Pvt. Ltd.
- Joel R. Hass, Christopher E.Heil, Maurice D. Weir, Thomas Calculus (14th Edition) Pearson
- Simmons, G. F.(2003) *Introduction to Topology and Modern Analysis* (4th edition), McGraw Hill.
- Apostol, Tom M.Calculus Volume –II (2nd Edition), Wiley and Sons.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-C-502
Name of the Course: Linear Algebra

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 Hrs	60 Hrs

Course Learning Outcomes (CLOs)	1. Understand the basic concepts of vector spaces and linear transformations 2. Evaluate eigenvalues and eigenvectors of a matrix and the relation between eigenvalues, eigenvectors, diagonalization of a matrix or operators. 3. Able to analyze matrices with different forms. 4. Able to apply matrix theory across disciplines.

Unit	**Unit Title**	**Contents**
I	Vector Space and Linear Transformations	Review of vector spaces over fields. Linear transformations, isomorphism between the algebra of linear transformations and that of matrices, rank-nullity theorem, duality and transposes of linear transformations.
II	Eigenvalues and eigenvectors	Eigenvalues and eigenvectors, characteristic polynomials, minimal polynomials, Cayley Hamilton Theorem (without proof), triangulation, diagonalization, rational canonical form, Jordan canonical form.
III	Inner product space	Inner product spaces, Cauchy-Schwarz inequality, Gram-Schmidt process, Orthogonal projections Linear Functionals and adjoints of a linear transformation, Hermitian, self-adjoint, unitary and normal operators, Schur's theorem, Spectral Theorem for normal operators.
IV	Bilinear forms and SVD	Bilinear forms, symmetric and skew-symmetric bilinear forms, real quadratic forms, Sylvester's law of inertia. Singular Value Decomposition (SVD) and its applications (statement and illustrations only).

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*
Building proofs; Group discussions; Problem solving; Practice visualization

Suggested-teaching learning strategy
1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Friedberg, Insel and Spence (2016) Linear Algebra (4th edition), Person.
- Hoffman, K., Kunze, R. (2000) *Linear Algebra* (2nd edition) Prentice Hall of India Pvt. Ltd.,New Delhi.
- G. Strang, Linear Algebra and Its applications, Nelson Engineering, 4th Edn., 2007.
- S. Lang, Linear Algebra, Undergraduate Texts in Mathematics, Springer-Verlag, New York, 1989.
- P. Lax, Linear Algebra, John Wiley & Sons, 1997. H.E. Rose, Linear Algebra, Birkhauser, 2002.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-C-503
Name of the Course: Differential Equations

Course Credits		**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits		L/T/P: 3+1+0 Hrs	60 Hrs
Course Learning Outcomes (CLOs)		1. Understand the theory and methods for solving Ordinary Differential Equations (ODEs) with given initial or boundary conditions. 2. Develop analytic skill to solve the Ordinary Differential Equations (ODEs) using power series and special functions. 3. Understand the theory and methods to solve the Partial Differential Equations (PDEs) and its applications in different special equations. 4. Develop the knowledge of using the differential equations in the field Physics, Biology, Economics.	
Unit	**Unit Title**	**Contents**	
I	Initial and Boundary Value Problem	• Existence and uniqueness of solutions of IVP, method of successive approximations, System of first order approximations, Picards theorem. • Boundary value problem, Green function, Sturm-Liouville Theory.	
II	Series Solution and Special Functions	• Power series solution, second order equations, ordinary points, regular points and singular points. • Hermite polynomials, Legendre polynomials, Bessel functions, Gamma functions.	
III	Partial Differential Equations	• First order equations, Classification of second order PDE, canonical form second order linear equations with constant co-efficient, Elliptic and Parabolic partial differential equations. • One- and two-dimensional Heat equations, one- and two-dimensional Wave equations, one- and two-dimensional Laplace's equations.	
IV	Applications in Modelling	• Modelling on simple harmonic motion and Kepler's laws of planetary motion by using ODEs, modelling on Heat transfer and Wave propagation using PDE. • Logistic growth model and Lotka-Volterra model using ODE. • Solow-Swan model using ODE, Black-Scholes model using PDE.	

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

Handling the problems on ODEs and PDEs; Visualize and analyze the application of series solutions in some special functions; Dealing with some real-world problem by using PDEs; Handling and analyzing some mathematical models in different fields.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	Written	Oral	Integrated
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- "Partial Differential Equations: An Introduction" by Walter A. Strauss, 2nd Edition (2008), John Wiley & Sons, Inc.
- "Introduction to Partial Differential Equations" by Michael E. Taylor, 3rd Edition (2011), Springer.
- "Partial Differential Equations" by Lawrence C. Evans, 2nd Edition (2010), American Mathematical Society.
- "Ordinary Differential Equations" by Vladimir I. Arnold, 2nd Edition (2006), Springer.
- "Differential Equations, Dynamical Systems, and Linear Algebra" by Morris W. Hirsch, Stephen Smale, and Robert L. Devaney, 3rd Edition (2012), Academic Press.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-C-504
Name of the Course: Algebra-I

Course Credits	No. of Hours per Week	Total No. of Teaching Hours
4 Credits	L/T/P:3+1+0 Hrs	60 Hrs

Course Learning Outcomes (CLOs)	After completion of the course students will be: 1. Able to take more advanced courses in Algebra. 2. Able to solve problems on Algebra. 3. Understand the basic results of Algebra. 4. Able to apply it to solve problems in other fields.

Unit	Unit Title	Contents
I	**Basic concepts of groups**	Review of groups: properties, examples including Sn, Dn, $GL(n, \mathbb{R})$, subgroups, homomorphisms; Lagrange's theorem; normal subgroups, quotient groups; isomorphism theorems, correspondence theorem;
II	**Sylow's Theorem**	Group action, Burnside lemma and counting, conjugacy; Cayley's theorem, class equation, consequences for p-groups; conjugacy classes in Sn and An, simplicity of A_n; Sylow's theorems, applications of Sylow's theorems.
III	**Direct Products**	Free groups, External direct product of groups, internal direct products, semi direct products; fundamental theorem of finite abelian groups and applications.
IV	**Rings**	Ring homomorphisms, ideals, quotients, isomorphism theorems; direct products of rings; field of fractions of an integral domain; prime and maximal ideals, Irreducible and prime elements; PID, ED and UFD.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate any)*

- Use of abstract algebraic concepts to solve problems in other branches of Mathematics.
- Mathematical writing.

Suggested-teaching learning strategy
1. Lecture with interactive discussions and problem-solving activities.

2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	Written	Oral	Integrated
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

• Bhattacharya, P.B., Jain, S. K. and Nagpal S. R. (2000) Basic Abstract Algebra (3rd edition), Cambridge University Press.
• Jacobson, N. (2002) Basic Algebra I (3rd edition), Hindustan Publishing Corporation, NewDelhi.
• Dummit, D.S. and Foote, R.M (2003) Abstract Algebra, John Wiley & Sons
• Gallian, J. A. (1999) Contemporary Abstract Algebra (4th edition), Narosa Publishing House, New Delhi.
• Herstein, I. N. (2003) Topics in Algebra (4th edition), Wiley Eastern Limited, New Delhi.
• Fraleigh, J. B. (2002) A First Course in Abstract Algebra (4th edition), Narosa Publishing House, New Delhi.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-V-505
Name of the Course: Indian Contribution to Mathematics

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P:3+1+0 Hrs	60 Hrs

Course Learning Outcomes (CLOs)	1. Understanding of the historical development of mathematics in India. 2. Knowledge of the various branches of mathematics that were developed in India, including algebra, geometry, trigonometry, and calculus. 3. Ability to analyze and evaluate the impact of Indian mathematical concepts and techniques on the global development of mathematics. 4. Appreciation of the cultural and philosophical influences that shaped the development of mathematics in India.

Unit	**Unit Title**	**Contents**
I	Introduction to Indian Mathematics	• Historical overview of Indian mathematics • Influence of Indian mathematics on the world • Overview of Indian numerals and the decimal system • Concept of zero and its development in India
II	Ancient Indian Mathematics	• Vedas and Sulbasutras as sources of mathematical knowledge • Geometry in ancient Indian mathematics • Arithmetic operations and algebraic methods in ancient Indian mathematics • Trigonometry in ancient India
III	Contributions of Indian Mathematicians	• Aryabhata and his contributions to astronomy and mathematics • Brahmagupta and his contributions to algebra and number theory • Bhaskara II and his contributions to calculus • Madhava and his contributions to infinite series and calculus
IV	Indian Mathematics in the Medieval and Modern Period	• Development of Indian mathematics during the medieval period • Modern developments in Indian mathematics, including Ramanujan's contributions to number theory • Influence of Indian mathematics on modern mathematics.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate any)*
Read and analyze original texts; Presentations; Group Discussions.

Suggested-teaching learning strategy
1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- "Indian Mathematics: Engaging with the World from Ancient to Modern Times" by George Gheverghese Joseph (2012), Oxford University Press
- "Indian Mathematics: An Introduction" by George Rusby Kaye (2010), World Scientific Publishing
- "The Crest of the Peacock: Non-European Roots of Mathematics" by George Gheverghese Joseph (1991), Princeton University Press
- "A Concise History of Mathematics in India" by Bibhutibhushan Datta and Avadesh Narayan Singh (1995), New Delhi: Motilal Banarsidass.
- Geometry in ancient India by Saraswati Amma (1999, 2nd Ed.), Motilal Banarsidass.
- The mathematics of India: concepts, methods, connections, sources and studies in the history of mathematics and physical sciences by P.P. Divakaran (2018), Hindustan Book Agency.
- Mathematics in India by Kim Plofker (2009), Princeton University Press.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.

Course Code: MTH-S-506

Name of the Course: Mathematical Reasoning

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
2 Credits	L/T/P: 1+1+0 Hrs	30 Hrs

Course Learning Outcomes (CLOs)	1. Apply logical reasoning to mathematical problems and proofs 2. Use mathematical induction to prove statements 3. Apply proof techniques such as direct proof, proof by contradiction, and contrapositive 4. Understand the basic concepts of set theory and use them in problem-solving 5. Analyze and solve complex mathematical problems using reasoning skills

Unit	**Unit Title**	**Contents**
I	Introduction to Mathematical Reasoning	Formulation of various mathematical problems and addressing them with the use of following existing mathematical approaches: • Propositional logic and predicate logic • Mathematical proofs and proof techniques • Logical equivalences and quantifiers
II	Mathematical Reasoning Approaches	Model building and its application and execution in different context with the use of following established approaches: • Mathematical induction • Sets, functions, relations, and countability • Graphs/diagrams and combinatorics • Proof strategies and problem-solving techniques • Division Algorithm, Congruence relation.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*
Problem Solving; Read Mathematics Textbooks; Group Discussions; Practice Visualization.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (25 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class	Oral Test, Viva-Voce, Seminar	Presentation, Seminars

	(10+15)	Assignment, Home Assignment		
	Summative (25 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Problem solving strategies by Arthur Engel, 1999, Springer.
- "How to Prove It: A Structured Approach" by Daniel J. Velleman, 2006, Cambridge University Press.
- "Mathematical Thinking: Problem-Solving and Proofs" by John P. D'Angelo and Douglas B. West, 2012, Prentice Hall.
- "The Art of Mathematics: Coffee Time in Memphis" by Béla Bollobás, 2006, Cambridge University Press.
- "Proofs and Refutations: The Logic of Mathematical Discovery" by Imre Lakatos, 1976, Cambridge University Press.
- "The Princeton Companion to Mathematics" edited by Timothy Gowers, 2008, Princeton University Press.

Note**: Latest edition of text books and reference books may be used.**

Semester-II

Name of the Programme: M.Sc.
Course Code: MTH-C-551
Name of the Course: Complex Analysis

Course Credits		**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits		L/T/P:3+1+0 Hrs	60 Hrs
Course Learning Outcomes (CLOs)		After completion of the course students will be: 1. Able to take more advanced courses in Complex Analysis. 2. Able to solve problems on complex analysis. 3. Understand the basic results of the complex analysis 4. Able to apply it to solve problems in other fields.	
Unit	**Unit Title**	**Contents**	
I	Holomorphic Functions	Holomorphic Functions, Cauchy-Riemann Equations and its Applications, Sufficient conditions for differentiability of complex functions, Taylor Series expansion of Holomorphic functions, Harmonic functions	
II	Complex Integration	Integration of complex valued functions along a rectifiable curve in C, Winding number of a closed curve about points in C, Cauchy-Goursat theorem, Cauchy's integral formula, Cauchy's estimate, Liouville's theorem, Morera's theorem, Fundamental theorem of algebra, Maximum modulus theorem, Schwarz lemma, Identity theorem, Open mapping theorem.	
III	Singularities and Residues	Laurent series expansion of a holomorphic function in an annulus, Singularities of complex functions, isolated singularities, poles, removable singularities, essential singularities, Extended Complex Plane and its Stereographic projection, Residues and their calculus, Evaluation of definite integrals, Argument principle, Rouche's theorem.	
IV	Conformal mappings and Mobius Transformations	Complex form of equations of straight lines, half planes, circles, etc., Mobius Transformations, cross ratio, symmetry and orientation principle, Examples of images of regions under Mobius Transformations.	

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*
Problem Solving; Read Textbooks; Group Discussions; Practice Visualization

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Modes	Written	Oral	Integrated
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Suggested Readings

- Elias M. Stein and Rami Shakarchi; Complex Analysis, 2003, Princeton University Press.
- L. V. Ahlfors; Complex Analysis; McGraw-Hill; New York, 1979 (Third Edition).
- R. V. Churchill and J. W. Brown; Complex Variables and Applications: McGraw-Hill; New York, 1996.
- J. B. Conway; Functions of One Complex Variable; Narosa Publishing, New Delhi, 1973.
- S. Lang; Complex Analysis, Fourth edition; Springer-Verlag, 1999.
- A. I. Markushivich; Theory of Functions of Complex Variables, Vol-I, II; Prentice-Hall, 1965.
- S. Ponnusamy; Foundations of Complex Analysis; Narosa Publishing; New Delhi, 1973.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: MSc
Course Code: MTH-C-552
Name of the Course: Algebra-II

Course Credits	No. of Hours per Week	Total No. of Teaching Hours
4 Credits	L/T/P: 3+1+0 hrs	60 hrs

Course Learning Outcomes (CLOs)

1. Able to learn field extensions, finite fields, Galois group, application of field theory in ruler-compass constructions and solvability of polynomials by radicals.
2. Able to take more advanced courses in algebra.
3. After this course students will be motivated to pursue a research career in algebra.

Unit	Unit Title	Contents
I	**Field Extensions**	Polynomial Rings, the Euclidean Algorithm, irreducibility, Gauss's Lemma, Eisenstein's Criterion, reduction Modulo p, zeros of polynomials field extension, finite and algebraic extensions.
II	**Solvable groups and Finite Fields**	Normal series, composition series, nilpotent groups, Jordan-Holder theorem (statement only); solvable groups, solvability by radicals; solvability of algebraic equations; Algebraic closure, splitting field, normal extensions, separable extensions, primitive element theorem; finite fields, inseparable extensions.

III	**Galois Group**	Galois extensions, fixed field, Galois group, fundamental theorem of Galois theory, some examples, roots of unity, cyclic extensions.
IV	**Ruler and Compass Constructions**	symmetric functions; radical extensions, solution by radicals, an insoluble quantic; Constructions in C, specific constructions, impossibility Proofs.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*
- Problem solving.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Lang, Serge, Algebra, Springer.
- Stewart Ian, Galois Theory, CRC Press
- T. I. F. R. Mathematical pamphlets, No. 3, (1965) Galois Theory.
- Artin, Emil (1997) Algebra with Galois Theory, American mathematical Society.
- Fraleigh, J. B. (2002) A First Course in Abstract Algebra (4th edition), Narosa Publishing House, New Delhi.

Name of the Programme: M.Sc.
Course Code: MTH-C-553
Name of the Course: Topology

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 Hrs	60 Hrs

Course Learning Outcomes (CLOs)	After completion of the course's students will be: 1. Able to take more advanced courses in topology and geometry like algebraic topology, differential topology, differential geometry etc. 2. Students will have a solid foundation for other courses in mathematics like, complex analysis, functional analysis, algebraic geometry. 3. This course is organized in such a way that after this course a student will have a solid background in elementary topology.

Unit	**Unit Title**	**Contents**
I	Topological Spaces and continuous functions	Definition and examples of topological spaces, basis and sub basis, subspace topology; continuity, product topology, quotient topology
II	Connectedness and compactness	Connected spaces, local connectedness, path connectedness, local path-connectedness, compact spaces, limit point compactness; local compactness, Tychonoff theorem, one point compactification.
III	Countability and separation axioms	Countability axioms, separation axioms, Urysohn lemma, Tietze extension theorem.
IV	Topological manifolds and simplicial complexes	Topological manifolds, simplicial complexes, cell complexes and CW complexes, classification of 1-Dimensional Manifolds.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Problem solving.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Munkres, J. R. (2000) Topology: a First Course, Prentice-Hall of India Ltd., New Delhi.
- Willard, S. (1970) General Topology, Addison-Wesley Publishing Company, Massachusetts.
- Kelley, J. L. (1990) General Topology, Springer Verlag, New York.
- Armstrong, M. A. (2005) Basic Topology, Springer International.
- Simmons G.F., Introduction to Topology and Modern Analysis, Mc Graw Hill Ed.
- Lee John M., Introduction to topological manifolds, Springer
- Joshi, K. D. (2002) An Introduction to General Topology, Wiley Eastern Ltd., New Delhi.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-S-556
Name of the Course: Scientific Computing

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
2 Credits	L/T/P: 1+0+2 Hrs	30 Hrs

Course Learning Outcomes (CLOs)

1. Apply computational tools to solve mathematical problems and perform simulations.
2. Develop and implement algorithms for solving complex mathematical problems.
3. Use programming languages such as Python and MATLAB to write efficient and effective code for solving mathematical problems.
4. Apply computational mathematics to real-world problems in fields such as science, engineering, finance, and economics.

Unit	**Unit Title**	**Contents**
I	Introduction to Computing	• Introduction to programming languages such as Python, R and MATLAB • Monte Carlo simulations and random number generation • Applications of computational mathematics in science and engineering
II	Basic Computing Techniques	• Optimization algorithms and techniques • Parallel computing and high-performance computing • Machine learning and data analysis using computational tools • Applications of computational mathematics in finance, economics, and other fields.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Developing Algorithms
- Coding
- Analyzing Simulation Results
- Applying Computational Mathematics to Real-World Problems.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars

	Summative (0 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- "Numerical Methods in Engineering with Python 3" by Jaan Kiusalaas, 2013, Cambridge University Press.
- "Numerical Recipes: The Art of Scientific Computing" by William H. Press et al., 2007, Cambridge University Press.
- "Numerical Linear Algebra" by Lloyd N. Trefethen and David Bau III, 1997, SIAM.
- "Numerical Optimization" by Jorge Nocedal and Stephen J. Wright, 2006, Springer.
- "Introduction to Computational Science: Modeling and Simulation for the Sciences" by Angela B. Shiflet and George W. Shiflet, 2006, Princeton University Press.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-V-557
Name of the Course: Cyber Security

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
2 Credits	L/T/P: 1+0+2 Hrs	30 Hrs

Course Learning Outcomes (CLOs)	1. Understand the concepts and principles of cyber security and the challenges it presents in today's digital world. 2. Identify different types of cybercrimes and their impact on individuals, organizations, and society. 3. Analyze the modus operandi of cybercriminals and develop strategies to report and address cyber-crimes effectively. 4. Apply remedial and mitigation measures to protect against cyber threats and ensure data security.

Unit	**Unit Title**	**Contents**
I	Basics of cyber security	Introduction to cyber security. Issues and challenges of cyber security. Cybercrimes and cyber laws. Cybercriminals modus-operandi, Reporting of cyber-crimes, Remedial and mitigation measures, Legal perspective of cybercrime, IT Act 2000 and its amendments. Case Studies.
II	Utilities of cyber security	e-commerce and Digital Payments. E-Commerce security. Banking Cards, Unified Payment Interface (UPI), e-Wallets, Unstructured Supplementary Service Data (USSD), Aadhar enabled payments, Digital payments related common frauds and preventive measures. RBI guidelines on digital payments and customer protection in unauthorized banking transactions. Relevant provisions of Payment Settlement Act,2007. National cyber security policy and strategy

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Lecture with interactive discussions and problem-solving activities.
- Assignments and individual presentations.
- Student-led classroom teaching.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	Written	Oral	Integrated
Formative (25 Marks) **(10+15)**	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (25 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Cyber Security Understanding Cyber Crimes, Computer Forensics and Legal Perspectives by Sumit Belapure and Nina Godbole, Wiley India Pvt. Ltd.
- Information Warfare and Security by Dorothy F. Denning, Addison Wesley.
- Security in the Digital Age: Social Media Security Threats and Vulnerabilities by Henry A. Oliver, Create Space Independent Publishing Platform.
- Data Privacy Principles and Practice by Natraj Venkataramanan and Ashwin Shriram, CRC Press.
- Information Security Governance, Guidance for Information Security Managers by W. KragBrothy, 1st Edition, Wiley Publication.
- Auditing IT Infrastructures for Compliance By Martin Weiss, Michael G. Solomon, 2nd Edition, Jones Bartlett Learning.

Note**: Latest edition of text books and reference books may be used.**

Semester-III

Name of the Programme: M.Sc.
Course Code: MTH-C-601
Name of the Course: Functional Analysis

Course Credits	No. of Hours per Week	Total No. of Teaching Hours
4 Credits	L/T/P: 3+1+0 hrs	60 hrs

Course Learning Outcomes (CLOs)	1. In-depth knowledge of Banach space, Bounded Linear operators and their properties. 2. Understand Open and Closed graph Theorem and their applications. 3. Comprehensive knowledge of Hilbert space and Bounded Linear operators on Hilbert space and their properties. 4. Learn adjoint operator and various structure of linear operators and its properties.

Unit	Unit Title	Contents
I	Normed Linear Spaces and Banach Spaces.	Normed Linear Spaces and Banach Spaces, Continuity of linear maps, Bounded Linear Operators, Duals, Hahn-Banach extension theorem.
II	Open mapping and closed graph theorems.	Uniform boundedness principle and its applications to Fourier series. Open mapping, closed graph theorems and their applications, Dual spaces, reflexive spaces; Spectrum of a bounded linear operators and compact linear operators, Examples of compact linear operators on normed spaces.

III	Inner product space	Inner product spaces, Hilbert Spaces, bounded linear operators on Hilbert spaces, orthogonal sets, orthonormal Basis, projection theorem, Riesz representation theorem.
IV	Adjoint operator	Adjoint operator, Self-adjoint, normal and unitary operators and their spectra, spectral theorem for compact operators

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Building proofs
- Group discussions
- Problem solving
- Practice visualization

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Bachman and Narici, Functional Analysis, Dover Books on Mathematics, 2003.
- E. Kreyzig, Introduction to Functional Analysis with Applications, John Wiley & Sons, New York, 1978.
- B.V. Limaye, Functional Analysis, 2nd Edition, New Age International, New Delhi, 1996.
- J.B. Conway, A Course in Functional Analysis, 2nd Edition, Springer, Berlin, 1990.
- C. Goffman and G. Pedrick, A First Course in Functional Analysis, Prentice-Hall, 1974.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-S-609
Name of the Course: Data Analysis

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
2 Credits	L/T/P: 1+0+2 Hrs	30 Hrs

Course Learning Outcomes (CLOs)

1. Understand the principles of statistical inference and its application to data analysis.
2. Use mathematical techniques to analyze and interpret data from various sources.
3. Apply regression analysis to model the relationships between variables.
4. Understand hypothesis testing and its role in data analysis.
5. Create visualizations of data to communicate insights effectively.

Unit	**Unit Title**	**Contents**
I	Data descriptions	Types of data and data sources; Basic statistical concepts; Probability concepts Statistical Inference: Point estimation, Interval estimation, Hypothesis testing.
II	Data Analysis	Simple linear regression, Multiple regression, Model selection, Logistic regression, Discriminant analysis, Naive Bayes. Classification: Clustering and Dimensionality Reduction, K-means clustering, Principal Component Analysis (PCA), Singular Value Decomposition (SVD).

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Problem Solving
- Read Mathematics Textbooks
- Group Discussions.
- Practice Visualization.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Introduction to Mathematical Statistics by Robert V. Hogg, Allen T. Craig, and William S. Mason (8th edition, 2018, Pearson Education)
- Probability and Statistics for Engineers and Scientists by Jay L. Devore (9th edition, 2019, Cengage Learning)
- Data Analysis: A Model-Based Approach by David Freedman, Robert Pisani, and Roger Purves (4th edition, 2018, W.H. Freeman and Company)
- Introduction to Statistical Learning by Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani (2nd edition, 2013, Springer)
- Thinking Stats by Allen B. Downey (2nd edition, 2013, O'Reilly Media)

Note**: Latest edition of text books and reference books may be used.**

Semester-IV

Name of the Programme: MSc
Course Code: MTH-S-657
Name of the Course: Modelling and Machine Learning

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
2 Credits	L/T/P: 1+0+2 hrs	30 hrs

Course Learning Outcomes (CLOs)

1. Visualize and analyze data using different tools.
2. Model the data with both single and multivariable functions.
3. Understand and apply the properties of different types of functions to apply them accordingly to model different situations.
4. Understand and apply the basic concepts in ML.
5. Understand and apply the fundamentals of CNN and the concept of transfer learning.

Unit	**Unit Title**	**Contents**
I	Mathematical Modelling	Linear Modeling, Exponential Modeling. Modeling with other Functions such as polynomial, periodic and power functions. Dimensional Analysis. Model fitting with real data and various methods of model parameter estimation and sensitivity analysis.
II	Introduction to Machine Learning	Basic concepts in machine learning. types of learning, model training & testing, overfitting, loss function; Linear regression, Logistic Regression, Support Vector Machine (SVM), Optimization Techniques, Gradient Descent, stochastic gradient descent; Neural network: Perceptron, multilayer network, backpropagation, introduction to deep neural network; Convolutional Neural Network (CNN), Building blocks of CNN, Transfer Learning.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Use of mathematical and computational tools.
- Handling and analyzing real-world data.
- Express problem using mathematical terms and getting its solutions.
- Organize, visualize, and analyze the data.
- Develop mathematical models and interpret its results.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- "Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow" by Aurélien Géron (2019) published by O'Reilly Media.
- "Python Machine Learning" by Sebastian Raschka and Vahid Mirjalili (2017) published by Packt Publishing.

- "An Introduction to Statistical Learning: with Applications in R" by Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani (2017) published by Springer.
- "The Hundred-Page Machine Learning Book" by Andriy Burkov (2019) published by Andriy Burkov.
- "Deep Learning" by Ian Goodfellow, Yoshua Bengio, and Aaron Courville (2016) published by MIT Press.

List of elective/open elective courses for Semester-III, and IV

(Some elective papers will be offered as open electives considering interest and need of students from other departments and interdisciplinary interests of faculty members)

Name of the Programme: M.Sc
Course Code: MTH-E-604; Name of the Course: Measure Theory

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 hrs	60 Hrs

Course Learning Outcomes (CLOs)	After completion of the course students will be: 1. Able to take more advanced courses in analysis. 2. Able to solve problems on analysis 3. Understand the basic results of analysis. 4. Able to apply it to solve problems in other fields.

Unit	**Unit Title**	**Contents**
I	Lebesgue Measure	Algebras, sigma-algebras, monotone classes, Lebesgue outer measure and Caratheodory's extension theorem; existence of Lebesgue measure and of non-measurble sets, Cantor set, Borel Set.
II	Lebesgue Integration	Measurable functions, monotone approximability by simple functions, Lebesgue integration; standard limit theorems: Fatou's lemma, monotone convergence and dominated convergence theorems; almost everywhere considerations.
III	Measures on Product Space	Abstract measure space, L^p-spaces, Product measures, Theorems of Tonelli and Fubini, independence and product measures, infinite products and finite state Markov Chains, Kolmogorov consistency theorem, Characteristic funcions, Modes of convergence.
IV	Random variables and Distributions	Probability, random variables and their distributions, joint distributions and independence, Borel-Cantelli lemma and Kolmogorov's zero-one law, Some of the more standard distributions – both discrete (Bernouilli, Binomial, Poisson, etc.) and continuous (Uniform, Normal, etc.); a brief introduction to conditional expectations and probabilities.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Problem solving.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its

practicality.

Suggested Readings

- Sheldon Axler; Measure, Integration and Real Analysis; Graduate text in Mathematics, Springer Nature Switzerland, 2020.
- G. De. Barra; Measure Theory & Integration; Wiley Eastern Limited, 1987.
- Charles Schwartz; Measure, Integration & Function Spaces; World Scientific, 1994.
- Inder Kumar Rana; An Introduction to measure & Integration; Narosa Publishing House, 1997.
- P. R. Halmos; Measure Theory; D.Van Nostrand Co. inc. London, 1962.
- P. K. Jain & V. P. Gupta; Lebesgue Measure & Integration; New Age International(P)limited Publishing Co, New Delhi, 1986.
- H. L. Royden; Real Analysis; Macmillan Pub.Co.inc 4th Edition, New York, 1993.
- Walter Rudin; Real and Complex Analysis; Tata McGraw Hill Publishing Co limited, New Delhi, 1966.
- Ali Grami; Probability, Random Variables, Statistics, and Random Processes: Fundamentals & Applications, John Wiley and Sons Inc. 2019.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.

Course Code: MTH-E-605; Name of the Course: Algebraic Topology

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 hrs	60 Hrs

Course Learning Outcomes (CLOs)

After completion of the course students will be:

1. Able to understand elementary concepts of algebraic topology like category and functors, homotopy, fundamental groups, covering spaces, homology groups etc.
2. Students will have a solid background in elementary algebraic topology.
3. Able to take more advanced courses in algebraic topology.
4. Students will be motivated to pursue research career in topology and allied areas.

Unit	**Unit Title**	**Contents**
I	Fundamental Group	Category and functors, homotopy, Retraction and deformation, fundamental group of a topological space, simply connected spaces, fundamental group of a topological group, Van Kampen's theorem, Brouwer's fixed point theorem.
II	Covering spaces	Covering spaces, homotopy lifting property, relations with the fundamental group, lifting problem, classification of covering proiections, covering transformations.
III	Homology	Chain complexes, chain homotopy, homology of simplicial complexes, singular homology, relative homology.
IV	Computation and Application of Homology	Exactness, Mayer- Vietoris sequences, Some applications of homology, Axiomatic characterization of homology.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Problem solving.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Modes	Written	Oral	Integrated
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Suggested Readings

- Hatcher, A. (2002) Algebraic Topology, Cambridge University Press.
- Spanier, E. H. (2000) Algebraic Topology (2nd edition), Springer-Verlag, New York.
- Rotman, J. J. (2004) An Introduction to Algebraic Topology, Text in Mathematics, No. 119, Springer, New York.
- Massey, W. S., A Basic Course in Algebraic Topology, Graduate Texts in Mathematics 127, Springer-Verlag, 1991.
- Greenberg, M. J. and Harper, J. R. (1997) Algebraic Topology: A First Course (2nd edition), Addison-Wesley Publishing

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-E-606; Name of the Course: Differentiable Manifolds

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 hrs	60 hrs

Course Learning Outcomes (CLOs)

After completion of the course students will be:
1. Able to understand elementary concepts of topological manifolds and differential verities.
2. Students will have a solid background in elementary geometry.
3. Able to take more advanced courses in manifold theory.

Unit	Unit Title	Contents
I	Differentiable Manifold and Smooth Map	Differentiable manifold, smooth maps, Tangent vector, tangent bundle, vector field, push forward, Covector, cotangent bundle, pullback, differential of function.
II	Submanifold	Submanifold, immersion, submersion, transversality , Sard theorem and Morse function, Whitney embedding.
III	Vector Bundle	Poincare-Hopf theorem, fibre bundles, vector Bundles, tensor product, wedge product.
IV	Differential forms	Differential form, exterior derivative, orientation, integration, Stokes theorem, De Rham cohomology

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*
- Problem solving.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Modes	Written	Oral	Integrated
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Suggested Readings

- Lee, John M. Introduction to smooth manifold, . Springer Verlag
- Lawrence Conlon; Differentianle Manifolds, Birkauser.
- Guillemin, Victor; Pollack, Alan. Differential topology. Prentice-Hall, Inc.,
- Hirsch, Morris W. Differential topology, Springer-Verlag, New York, 1994
- Milnor, John W. Topology from the differentiable viewpoint.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-E-607; Name of the Course: Field Theory

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 hrs	60 Hrs

Course Learning Outcomes (CLOs)

1. Able to learn field extensions, finite fields, Galois group, application of field theory in ruler-compass constructions and solvability of polynomials by radicals.
2. Able to take more advanced courses in algebra.
3. After this course students will be motivated to pursue research career in algebra.

Unit	**Unit Title**	**Contents**
I	Field Extensions	Review of the Euclidean Algorithm, irreducibility, Gauss's Lemma, Eisenstein's Criterion, reduction Modulo p, zeros of polynomials field extension, finite and algebraic extensions.
II	Algebraic Closure and Finite Fields	Algebraic closure, splitting field, normal extensions, separable extensions, primitive element theorem; finite fields, inseparable extensions.
III	Galois Group	Galois extensions, fixed field, Galois group, fundamental theorem of Galois theory, some examples, roots of unity, cyclic extensions.

IV	Ruler and Compass Constructions	Review of solvable groups, sovability by radicals; solvability of algebraic equations; symmetric functions; radical extensions, solution by radicals, an insoluble quantic; Constructions in C, specific constructions, impossibility Proofs.

Skill Developments Activities: *(These activities are only indicative; the faculty member can innovate)*

- Problem solving.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Suggested Readings

- Lang, Serge, Algebra, Springer.
- Stewart Ian, Galois Theory, CRC Press
- T. I. F. R. Mathematical pamphlets, No. 3, (1965) Galois Theory.
- Artin, Emil (1997) Algebra with Galois Theory, American mathematical Society.
- Fraleigh, J. B. (2002) A First Course in Abstract Algebra (4th edition), Narosa Publishing House, New Delhi.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-E-651; Name of the Course: Commutative Algebra

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 hrs	60 Hrs

Course Learning Outcomes (CLOs)	1. After this course students will be able to take more advanced courses in Commutative Algebra and Algebraic Geometry. 2. Able to solve advanced problems in algebra.

Unit	**Unit Title**	**Contents**
I	Rings and Ideals	A brief review of rings, ideals and homomorphisms, Operations on ideals, Extension and contraction of ideals, Nil radical and Jacobson radical.
II	Modules	Modules, sub modules, homomorphism, direct sum and products of modules, exact sequences, Tensor product of modules and algebras and basic properties.

III	Rings and Modules of fractions, Primary Decomposition	Rings and modules of fractions, Extension and contraction of ideals of them, primary decomposition, Integral dependence, Going up and going down theorems, Valuation rings
IV	Noetherian and Artinian Rings	Noetherian rings, Artinian rings and their basic properties, Hilbert Basis Theorem, Structure theorem for Artinian rings.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Problem solving.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- M. F. Atiyah & I. G. Macdonald, Introduction to Commutative Algebra, Addison-Wesley Publishing Company, Inc., 1969.
- David Eisenbud, Commutative Algebra with a view towards Algebraic Geometry, Springer-Verlag, 19960.
- Irving Kapalansky– Commutative Rings, Springer-Verlag, 1973.
- N. S. Gopalakrishnan – Commutative Algebra, Oxonian Press Pvt. Ltd., 1984.
- Oscar Zariski, Pierre Samuel, Commutative Algebra, D. Van Nostrand Company, 1965.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-O-554; Name of the Course: Numerical Methods

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 2+1+2 hrs	60 Hrs

Course Learning Outcomes (CLOs)		1. Apply numerical methods to solve mathematical problems and perform simulations. 2. Develop and implement algorithms for solving mathematical problems. 3. Use programming languages such as Python and MATLAB to write efficient and effective code for solving numerical problems.
Unit	**Unit Title**	**Contents**
I	Basics of numerical	Numerical error analysis and sources of errors in numerical computations, Root Finding

	methods	Methods, Interpolation and Approximation Least squares approximation.
II	Numerical Differentiation and Integration	Numerical differentiation using finite difference methods, Numerical integration using trapezoidal and Simpson's rule, Gaussian quadrature, Comparison of numerical differentiation and integration methods.
III	Initial and Boundary Value Problems	Solution of ordinary differential equations (ODEs) using Euler's method and Runge-Kutta methods, Solution of partial differential equations (PDEs) using finite difference methods, Solution of initial and boundary value problems using finite element method
IV	Numerical simulations	Monte Carlo methods, Optimization techniques, Solution of linear and nonlinear systems of equations, minor project works.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*
Problem solving; Group discussions; Algorithm development; Numerical simulation.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Suggested Readings

- "Numerical Methods for Engineers and Scientists: An Introduction with Applications using MATLAB" by Amos Gilat and Vish Subramaniam, published in 2013 by Wiley.
- "Numerical Methods in Engineering with MATLAB®" by Jaan Kiusalaas, published in 2005 by Cambridge University Press.
- "Numerical Methods for Partial Differential Equations: Finite Difference and Finite Volume Methods" by Sandip Mazumder, published in 2016 by CRC Press.
- "Numerical Methods for Scientists and Engineers" by Richard Hamming, published in 1987 by Dover Publications.
- "Numerical Methods Using MATLAB" by John H. Mathews and Kurtis D. Fink, published in 2004 by Prentice Hall.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-E-608; Name of the Course: Dynamical Systems

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 2+1+2 hrs	60 Hrs

Course Learning Outcomes (CLOs)	1. Apply ODE/PDE methods to solve mathematical problems and perform simulations. 2. Understand the concepts and important results of Dynamical Systems. 3. Use programming languages such as Python and MATLAB to write efficient and effective code for solving mathematical models.

Unit	**Unit Title**	**Contents**
I	Linear Systems	Fundamental theorem, Diagonalization, Jordan forms, Linear Systems in R^2, Complex and multiple eigen values, stable and unstable subspaces, nonhomogeneous linear systems.
II	Nonlinear systems: local analysis	: local analysis Fundamental theorem, the maximum interval of existence, nonlinear flow, Linearization, Hartman-Grobman theorem, Stable manifold and Central manifold theorem, Stability and Liapunov functions.
III	Nonlinear systems: global analysis	Global existence theorem, Limit sets and attractors, Periodic orbits, limit cycles and separatrix cycles, Poincare map, Poincare-Bendixson theory in R^2, Bendixson's criteria.
IV	Bifurcation theory	Structural stability, Hopf bifurcations, Global behaviour of one-parameter families of periodic orbits, homoclinic bifurcations, bifurcation systems in R2 .

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*
Problem solving; Group discussions; Algorithm development; Numerical simulation.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Drazin, P.G. (1992) Nonlinear Systems. Cambridge University Press.
- Perko, L. (2000) Differential Equations and Dynamical Systems (3rd Edition). Springer.
- Ott, E. (2002) Chaos in Dynamical Systems. Cambridge University Press.
- Guckenheimer, J., Holmes, P. (1983) Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields. Springer

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc. Course Code: MTH-E-652; Name of the Course: Graph Theory			
Course Credits		**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits		L/T/P: 3+1+0 hrs	60 hrs
Course Learning Outcomes (CLOs)		1. Apply graph and graph-based methods to solve complex problems. 2. Understand the concepts and important results of Graph Theory. 3. Use mathematical software to draw and analyze s different graphs.	
Unit	**Unit Title**	**Contents**	
I	Fundamental concepts	Simple graphs, pseudo graphs, isomorphism, paths, connected graphs, bipartite graphs, vertex degree; Turan's theorem, degree sequences, graphical sequences, degree and digraphs.	
II	Tree and Distances	Properties of tree, distance in graphs, disjoint spanning trees, adjacency matrices, Kruskal's algorithm, Prim's algorithm for minimum spanning tree, Dijkstra's algorithm for shortest path, Floyd-Warshall Algorithm, Eulerian circuits.	
III	Matching and Factors	Matching in bipartite graphs, maximum matching, Hall`s matching conditions, Min-Matching in bipartite graphs, sets, applications and algorithms, maximum bipartite matching, weighted bipartite matching in general graphs.	
IV	Connectivity and Paths	Cuts, connectivity, edge-connectivity, blocks, 2- connected graphs, connectivity of digraphs, k connected and k-edge connected graphs, applications of Menger`s theorem, planarity and coloring graphs (up to 5 coloring).	

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*
Problem solving; Group discussions; Algorithm development.

Suggested-teaching learning strategy
1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Suggested Readings

- Douglas B. West (1999) Introduction to Graph Theory. Prentice- Hall, New Delhi
- Bondy,J. A. and Murty,U.S.R (2008) Graph Theory with Applications, Springer
- Harary (1989) Graph Theory. Narosa Publishers, New Delhi
- Deo, Narsingh (1974) Graph Theory with Applications to Engineering and Computer Science Prentice-Hall Series in Automatic Computation, Prentice-Hall.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-E-653; Name of the Course: Mathematical Biology

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 2+1+2 hrs	60 Hrs

Course Learning Outcomes (CLOs)

1. Apply mathematical models and methods to solve biological problems.
2. Develop models to address biological questions.
3. Analyze and interpret biological data.

Unit	**Unit Title**	**Contents**
I	Mathematical models in biology	Standard mathematical models in ecology and epidemiology; mathematical models in physiology; mathematical models at cells and tissue; Genetic regulatory models.
II	Biological data and bioinformatics	DNA, RNA and protein sequences; algorithms of sequence alignments; phylogenetic tree constructions; protein 3D structure and structural bioinformatics tools.
III	Statistical data analysis and modelling	Statistical modelling; Data fitting to models; machine learning techniques: supervised and unsupervised classifications, regressions, neural nets.
IV	Systems biology	Biological network; network analysis using graph theory, dynamic network, feedback and feedforward models for biological control systems.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*
Problem solving; Group discussions; Algorithm and model development.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Simon, W. (1978) Mathematical Techniques for Biology and Medicine. MIT Press.
- Murray, J.D. (1990) Mathematical Biology. Springer.
- He, M., Petoukhov, S. (2011) Mathematics of bioinformatics: theory, practice and applications by John Wiley & Sons Inc.
- Zhang, Y.Q., Rajapakse, J.C. (2008) Machine learning in bioinformatics by Yan-Qing Zhang and Jagath C. Rajapakse, John Wiley & Sons Inc.
- Alon, U. (2020) An introduction to systems biology-design principles of biological circuits (2nd edition), Chapman & Hall/CRC publishers.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: MSc

Course Code: MTH-O-555; Name of the Course: Optimization Techniques

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 hrs	60 hrs

Course Learning Outcomes (CLOs)	1. Formulate optimization problem. 2. Understand various numerical methods for solving different types of linear and nonlinear programming problems. 3. Solve transportation and assignment problems. 4. Formulate game problems and provide solutions.

Unit	**Unit Title**	**Contents**
I	**Linear Programming Problem**	Preliminary theory, geometry and Formulation of the General L.P.P, Simplex Method, revised simplex method, duality and its principles. Primal- Dual method.
II	**Integer Programming**	Travelling Salesman Problem, Transport and Assignment Problem, Max flow-Min cut problem, Minimal spanning tree, shortest path problem.
III	**Non-Linear Optimization**	Nonlinear optimization: basic theory, method of Lagrange multipliers, Karush-Kuhn-Tucker theory, convex optimization.
IV	**Game theory**	Two-person zero-sum games, maximum criterion, dominance rules, mixed strategies, mini-max theorem, solutions of 2x2 and 2xm games.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Use of numerical tools.
- Handling and analyzing real-world data.
- Express problem using mathematical terms and getting its solutions.
- Organize, visualize, analyze and optimize data.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Hadley, G. (1966) Linear Programming, Addison.

- Gale, D. (1989) The Theory of Linear Economic Model, University of Chicago Press.
- Swarup, K, Gupta, P. K. and Mohan, M. (2002) Operations Research, Sultan Chand & Sons,New Delhi.
- Friderick S. H. and Gerald J. L. (1974) Operations Research, Holden-Day Inc, San Fransisco.
- Hamdy A. T. (2002) Operation Research: An Introduction, Prentice-Hall of India Pvt. Ltd.,New Delhi.
- M.S. Bazaraa, H.D. Sherali and C.M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley & Sons, 2013.

Name of the Programme: M.Sc.
Course Code: MTH-E-654; Name of the Course: Stochastic Processes

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 2+1+2 hrs	60 Hrs

Course Learning Outcomes (CLOs)

1. Apply and execute stochastic process for real-world situations.
2. Develop models to address complex problems.
3. Analyze and interpret large data.

Unit	**Unit Title**	**Contents**
I	Introduction to Probability Theory	Basic concepts of probability theory, Random variables (continuous and discrete), Expectation and variance of random variables, Commonly used probability distributions.
II	Markov Chains	Definition and properties of Markov chains, Classification of states, Finite-state Markov chains, Continuous-time Markov chains, Kolmogorov's differential equations, Applications of Markov chains.
III	Renewal Processes	Definition and properties of renewal processes: Interarrival time distribution, Renewal function, Renewal equation, Mean and variance of renewal processes, Applications of renewal processes
IV	Brownian Motion and Stochastic Calculus	Definition and properties of Brownian motion: Sample paths, Continuous trajectories, Gaussian distribution, Markov property; Stochastic processes and stochastic calculus: Ito's lemma, Stochastic differential equations (SDEs), Numerical solutions to SDEs; Applications of Brownian motion and stochastic calculus

Skill Developments Activities: (*These activities are only indicative; the Faculty member can innovate*)
Problem solving; Group discussions; Algorithm and model development.

Suggested-teaching learning strategy
1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- "Stochastic Processes" by Sheldon M. Ross, 2nd Edition, published in 1996 by John Wiley & Sons, Inc.
- "Introduction to Stochastic Processes" by Gregory F. Lawler, 2nd Edition, published in 2006 by Chapman & Hall/CRC.
- "Stochastic Processes: Theory for Applications" by Robert G. Gallager, 2nd Edition, published in 2013 by Cambridge University Press.
- "Stochastic Processes and Their Applications" by David Stirzaker and Geoff R. Grimmett, 3rd Edition, published in 2020 by Cambridge University Press.
- "An Introduction to Stochastic Processes with Applications to Biology" by Linda J.S. Allen, 2nd Edition, published in 2017 by CRC Press.

Note: Latest edition of text books and reference books may be used.

Name of the Programme: MSc
Course Code: MTH-O-602; Name of the Course: Matrix Analysis

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 Hrs	60 Hrs

Course Learning Outcomes (CLOs)		1. Able to localize the eigenvalues of a matrix using matrix norms and Gershgorin's theorem. 2. To apply Perron's theorem to positive matrices and the Perron-Frobenius theorem to nonnegative matrices. 3. Compute the matrix exponential and use it for solving differential and algebraic equations. 4. Learn advanced techniques and tools in matrix theory, linear algebra and its applications.
Unit	**Unit Title**	**Contents**
I	Matrix Norms	Review of eigenvalues and eigenvectors; Norms: Vector norms and matrix norms, bounds for eigenvalues, Gerschgorin theorem.
II	Nonnegative matrices	Nonnegative matrices, Examples, and related results. Irreducible matrices, Perron's theorem, Perron-Frobenius theorem, M-matrices.
III	Matrix Functions	Matrix Functions: Polynomial matrix functions and interpolations; Non-polynomial matrix functions; Hadamard matrix functions; Square roots, Logarithms, Nonlinear matrix equations; A chain rule for functions of a matrix.
IV	Matrix exponential	Matrix exponential, Definitions of the matrix exponential function and application to the solution of differential equations and higher order equations.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Learn advanced techniques and tools in matrix theory, linear algebra and its applications.
- Help to carried out better research in the related areas.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Modes	Written	Oral	Integrated
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Suggested Readings

- Rajendra Bhatia, Matrix Analysis, Springer, 1997
- Roger A. Horn and Charles R. Johnson, "Topics in Matrix Analysis", Cambridge University Press, 1999.
- G. Golub and C. VanLoan, "Matrix Computations", Johns Hopkins University Press, Baltimore, Third Edition.
- Roger A. Horn and Charles R. Johnson, "Matrix Analysis", Cambridge University Press, 1994.
- Peter Lancaster and Miron Tismenetsky. The Theory of Matrices. Academic Press, London, second edition, 1985.
- James M. Ortega. Matrix Theory: A Second Course. Plenum Press, New York, 1987.
- Carl D. Meyer. Matrix Analysis and Applied Linear Algebra. SIAM, 2000.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: MSc

Course Code: MTH-O-603; Name of the Course: Discrete Mathematics

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 Hrs	60 Hrs

Course Learning Outcomes (CLOs)

1. Understanding the foundational concepts and principles of discrete mathematics.
2. Developing problem-solving skills using discrete mathematics.
3. Enhancing computational skills.
4. Improving communication and collaboration skills.

Unit	Unit Title	Contents
I	Propositional and predicate logic	Propositional Logic: Propositional calculus and truth tables, Normal forms and completeness, Applications to digital circuits and switching networks; Predicate Logic: First-order logic and quantifiers, Predicate calculus and proof techniques, Models and semantics, Applications to programming languages and databases.
II	Boolean Algebra	Boolean algebras and Boolean functions, Boolean expressions and normal forms Minimization techniques and Karnaugh maps, Applications to logic design and digital circuits.
III	Algorithms	Complexity of algorithms: time and space complexity; Sorting algorithms: bubble sort, selection sort, insertion sort, quicksort, mergesort; Graph algorithms: breadth-first search, depth-first search, shortest path algorithms.
IV	Recurrence Relations	Definition and types of recurrence relations; Solution techniques: substitution, iteration, generating functions; Applications: counting problems, analysis of algorithms, Fibonacci sequence

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Framing and analyzing algorithms
- Computational skill.
- Interdisciplinary applications.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Modes	Written	Oral	Integrated
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Suggested Readings

- Discrete Mathematics and Its Applications by Kenneth H. Rosen, 7th edition, 2011, McGraw-Hill Education
- Concrete Mathematics: A Foundation for Computer Science by Ronald L. Graham, Donald E. Knuth, and Oren Patashnik, 2nd edition, 1994, Addison-Wesley.
- A Course in Combinatorics by J.H. van Lint and R.M. Wilson, 2nd edition, 2001, Cambridge University Press.
- Introduction to Algorithms by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, 3rd edition, 2009, MIT Press.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.

Course Code: MTH-E-655; Name of the Course: Curves and Surfaces

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	3+1+0 Hrs	60 Hrs

Course Learning Outcomes (CLOs)		After this course students will be able to 1. Take more advanced courses in differential geometry. 2. Understand the basic concepts of differential geometry like curves, surfaces, tangent vector, tangent plane and curvature etc. 3. Apply his/her knowledge to solve problems from Physics, Chemistry etc. For example, in computing surface areas, arc length, curvature etc.
Unit	**Unit Title**	**Contents**
I	**Vectors and derivatives of vector valued functions**	Review of total derivative, inverse and implicit function theorems, vectors in R^3; tangent vectors; translations; affine transformations and rigid motions (isometries).
II	**Curves**	Space curves; arc length; tangent vectors and vector fields on a curve; curvature and torsion; Serret-Frenet formulas; osculating plane; osculating circle; osculating sphere; fundamental theorem of local theory of space curves.

III	**Surfaces**	Surfaces and their (local) parametrization on coordinate systems; change of parameters; parametrized surfaces; curves on surfaces; tangent and normal vectors; tangent and normal vector fields on a surface; first, second and third fundamental forms of a surface at a point; Gauss mapping.
IV	**Curvature**	Normal sections and normal curvature of a surface at a point; Meusnier's theorem; elliptic, hyperbolic, parabolic and planar points; Dupin indicatrix; principal directions; principal curvatures of a surface at a point; Mean curvature and Gaussian curvature of a surface at a point. Line of curvature; asymptotic curves; conjugate directions; fundamental equations of the local theory of surfaces; statement of Bonnet's fundamental theorem of local theory of surfaces.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Problem solving.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Pressley, A. (2005) Elementary Differential Geometry, Springer International Edition.
- Docarmo Manfredo P. (1976) Differential Geometry of Curves and Surfaces, Prentice Hall.
- Hsiung, C. C. (1997) A first Course in Differential Geometry, International Press, University of Michigan.
- McCleary, John (1997) Geometry from a Differentiable Viewpoint, Cambridge University Press.
- Eissenhart, P. (1960) A Treatise on the Differential Geometry of Curves and Surfaces, Dover Publications, Inc., New York.
- Weatherburn, C. R. (1964) Differential Geometry of Three Dimensions, The English Language Book Society and Cambridge University Press.
- Willmore, T. S. (1979) An Introduction to Differential Geometry, Clarendon Press, Oxford.
- Klingenberg, V. (1978) A Course in Differential Geometry, Graduate Texts in Mathematics 51, Springer-Verlag.

Note**: Latest edition of text books and reference books may be used.**

Name of the Programme: M.Sc.
Course Code: MTH-E-656; Name of the Course: Algebraic Geometry

Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4 Credits	L/T/P: 3+1+0 Hrs	60 Hrs

Course Learning Outcomes (CLOs)	After this course students will be able to 1. Take more advanced courses in algebraic geometry. 2. Understanding of basic concepts of algebraic geometry like algebraic sets, affine algebraic sets, projective algebraic sets, Zariski topology, presheaves, sheave, affine scheme etc.

Unit	**Unit Title**	**Contents**
I	**Affine algebraic sets**	Affine spaces and algebraic sets, Noetherian rings, Hilbert basis theorem, affine algebraic sets as finite intersection of hypersurfaces; Ideal of a set of points, coordinate ring, morphism between algebraic sets, isomorphism. Integral extensions, Noether's normalization lemma.
II	**Hilbert's Nullstellensatz and applications**	Correspondence between radical ideals and algebraic sets, prime ideals and irreducible algebraic sets, maximal ideals and points, contrapositive equivalence between affine algebras with algebra homomorphisms and algebraic sets with morphisms, between affine domains and irreducible algebraic sets, decomposition of an algebraic set into irreducible components. Zariski topology on affine spaces, algebraic subsets of the plane.
III	**Projective spaces**	Homogeneous coordinates, hyperplane at infinity, projective algebraic sets, homogeneous ideals and projective Nullstellensatz; Zariski topology on projective spaces. Twisted cubic in P_3(k). Local properties of plane curves: multiple points and tangent lines, multiplicity and local rings, intersection numbers; projective plane curves: Linear systems of curves, intersections of projective curves: Bezout's theorem and applications; group structure on a cubic.
IV	**Introduction to sheaves of affine varieties**	Examples of presheaves and sheaves, stalks, sheafification of a presheaf, sections, structure sheaf, generic stalk and function fields, rational functions and local rings, Affine tangent spaces; Projective varieties and morphisms; Hausdorff axiom. Prime spectrum of a ring: Zariski topology, structiureaheaf, affine schemes, morphism of affine schemes. Elementary Dimension Theory, Fibres of a morphism, complete varieties, nonsingularity and regular local rings, Jacobian criterion, nonsingular curves and DVR's.

Skill Developments Activities: *(These activities are only indicative; the Faculty member can innovate)*

- Problem solving.
- Group discussions.

Suggested-teaching learning strategy

1. Lecture with interactive discussions and problem-solving activities.
2. Assignments and individual presentations.
3. Student-led classroom teaching.
4. Group discussions

Assessment Framework

Modes	**Written**	**Oral**	**Integrated**
Formative (50 Marks)	Class Test, Open Book Test, Quiz, Online Test, Class Assignment, Home Assignment	Oral Test, Viva-Voce, Seminar	Presentation, Seminars
Summative (50 marks)	End-Semester Examination conducted by the University		

Note: The course teacher may select an appropriate mode of formative assessment based on the nature of the Course Learning Outcomes (CLOs) and its practicality.

Suggested Readings

- Bartle, R.G. (1994) The Elements of Real Analysis (3rd edition), Wiley International
- W.Fulton Algebraic Curves: An introduction to algebraic geometry
- C. G. Gibson – Elementary Geometry of Algebraic Curves, CUP,
- Hartshorne Robin, Aleraic Geometry, Springer
- J. Harris Algebraic Geometry, A first course, Springer
- M. Reid Undergraduate algebraic geometry, LMS 12, CUP
- K. Kendig – Elementary Algebraic Geometry, Springer
- D. Mumford – The Red Book of Varieties and Schemes, Springer
- I. R. Shafarevich – Basic Algebraic Geometry, Springer

Note**: Latest edition of text books and reference books may be used.**