DEPARTMENT OF APPLIED MATHEMATICS,
FACULTY OF ENGG. & TECH.,
M.J.P.R.U., BAREILLY.

Syllabus of M.Sc. (Mathematics)

2022-23 onwards.

Vision

To recognize its academic excellence at international level by producing intellectuals, excellent academic leaders and researchers in the field of Mathematics as well as to be locally relevent through its role in the development of the community.

Mission

To establish a suitable platform for higher learning in Mathematics. This is in addition to its starting objective of providing Mathematical input to technical education only. The main emphasis in both the cases is to impart functional knowledge which not only motivates students towards academic excellence but also preparing them for giving back to society in economic, social, cultural and intellectual dimensions, conventional and innovative teaching methods.

Objectives

1. To create an atmosphere that encourages students and supports their efforts.
2. To produce qualified graduates who are equipped with deeper insight and research skills in the field of Mathematics.
3. To encourage participation in scientific forums and seminars and to encourage follow up of latest scientific research and techniques in Mathematics.
4. To encourage interdisciplinary research with other areas such as statistics, operation research, physics, branches of engineering etc.
5. To develop the independent research and analytical thinking abilities of our students along with research-based developments in teaching and education reform efforts.

Program Educational Objectives (PEOs)

1. Graduates will contributes rapidly growing multidisciplinary research that uses advanced computing capabilities to understand and solve complex problems.
2. Graduate of the programme will be capable of handling every problem existing around the world through mathematical structures.
3. Graduate of the programme will become competent users of mathematics and to provide mathematical solution to real life problems.
4. Graduates will continue lifelong learning and pursue higher studies in mathematical and statistical sciences.

Program Outcome:

Graduate will be able to

a) Progress the critical analysis and problem solving skills required for research and development organization and industry.

b) Communicate confidently and effectively with industry and society at large, regarding complex problem and solution of the problem, existing around.

c) Engage in dependent and lifelong learning with a high level of enthusiasm and commitment to improve knowledge and competence continuously.
d) Contribute significantly in academics through teaching and research.
e) Demonstrate knowledge and understanding of various structure of mathematics and apply the same to one's own work, as a member and leader in a team, manage projects efficiently after consideration of economical and financial factors.
f) Apply ethical principles and commit to professional ethics and responsibilities and norms of the professional practice.

Qualification Descriptors (Possible Career Pathways)

Upon successful completion of the course, the students receive a master degree in the Mathematics. M.Sc. Mathematics post-graduates of this department are expected to demonstrate knowledge of major portion of pure and applied mathematics and the ability to provide an overview of scholarly debates relating to Mathematics. Also it is expected that after the completion of this course they will be in a position to pursue the research in Mathematics. Along with mathematical skills, it is also expected that they will learn life skills of argumentation, communication and general social values which are necessary to live rich, productive and meaningful lives. The list below provides a synoptic overview of possible career paths provided by a postgraduate training in Mathematics:

1. Teaching

2. Research

3. Engineering

4. Computer programming (In different MNC's)

5. Statistician

6. Defense Research and Development Organization (DRDO) and Indian Space Research Organization (ISRO).

7. Can go for UPSC/Civil services exam.

8. Finance

9. Science and Business

SEMESTER WISE COURSES AND CREDIT DISTRIBUTION

CC – Core Course **DCEC – Discipline Centric Elective Courses**

GEC – Generic Elective Course **SEEC – Skill Enhancement Elective Course**

L – Lecture T – Theory P – Practical/Presentation

SEMESTER-I

Total Credits: 30 (Core Course)

Course No.	Course Code	Course name	L	T	P	Hrs/ Week	Total Credits
1	MA-511	Modern Algebra	4	2	0	6	5
2	MA-512	Real Analysis	4	2	0	6	5
3	MA-513	Introduction to Topology	4	2	0	6	5
4	MA-514	Difference Equations	4	2	0	6	5
5	MA-515	Optimization Techniques	4	2	0	6	5
6	MA-516	Seminar Presentation and Viva-Voce	0	0	10	10	5
					Total Credits		30

SEMESTER-II

Total Credits: 30(Core Course)

Course No.	Course Code	Course name	L	T	P	Hrs/ Week	Total Credits
7	MA-521	Linear Algebra	4	2	0	6	5
8	MA-522	Complex Analysis	4	2	0	6	5
9	MA-523	Advanced Topology	4	2	0	6	5
10	MA-524	Tensor Analysis and Elementary Differential Geometry	4	2	0	6	5
11	MA-525	Operations Research	4	2	0	6	5
12	MA-526	Powerpoint Presentation and Viva-Voce	0	0	10	10	5
					Total Credits		30

SEMESTER-III

Total Credits: 30(CC– 25, DCEC – 5, SEEC -0)

Course No.	Course Code	Course name	L	T	P	Hrs/ Week	Total Credits
13	MA-631	Functional Analysis	4	2	0	6	5
14	MA-632	Basic Statistics	4	2	0	6	5
15	MA-633	Fluid Dynamics	4	2	0	6	5
16	MA-634	Differential Equations	4	2	0	6	5
17	MA-635	Project/Dissertation	0	0	0	10	5
Discipline Centric Elective Courses							
18	MA-636	MOOC/DCEC	4	2	0	6	5
Discipline Centric Skill Based Courses							
19	MA-637	SEEC	1	1	2	4	0
					Total Credits		30

DCEC Courses offered for M.Sc. (Mathematics) students only

Course Code	Course name
MA-636(a)	Advanced Differential Geometry
MA-636(b)	Measure Theory and Integration
MA-636(c)	Mathematics for Finance and Insurance
MA-636(d)	Integral Equations
MA-636(e)	Bio-Mechanics

Note : Student can choose any one from DCEC Course as per the availability of the subject teachers/experts. Student may complete the course of his/her choice through MOOC.

SEEC (Skill Enhancement Elective Course, non-credit, only qualifying in nature): This may include a course based on Theoretical/Experimental/Computational Techniques/Methods. The department may offer more than one courses depending on specialization and strength of faculty members, and the student has to opt one of them.

Course Code	Course name
MA-637(a)	Programming in MATLAB
MA-637(b)	Programming in SCILAB
MA-637(c)	Artificial Intelligence and Machine Learning
MA-637(d)	Programming in C
MA-637(e)	Research Methodology

Note : Student can choose any one from SEEC Course as per the availability of the subject teachers/experts. Student may complete the course of his/her choice through MOOC.

SEMESTER-IV

Total Credits: 30(CC – 21, DCEC – 5, GEC -4)

Course No.	Course Code	Course name	L	T	P	Hrs/ Week	Total Credits
20	MA-641	Advanced Partial Differential Equations with Applications	4	2	0	6	5
21	MA-642	Advanced Mathematical Statistics	4	2	0	6	5
22	MA-643	Advanced Discrete Mathematics	4	2	0	6	5
23	MA-644	Project/Dissertation	0	0	12	12	6
Discipline Centric Elective Courses							
24	MA-645	MOOC/DCEC	4	2	0	6	5
Generic Elective Courses							
25	MA-646	MOOC/GEC (To be taken from other departments)	3	1	0	4	4
						Total Credits	30

DCEC Courses offered for M.Sc. (Mathematics) students only

Course Code	Course name
MA-645(a)	Theory of Relativity & Cosmology
MA-645(b)	Fuzzy Set Theory
MA-645(c)	Space Dynamics
MA-645(d)	Advanced Fluid Dynamics
MA-645(e)	Introduction to Cryptography
MA-645(f)	Mechanics
MA-645(g)	Wavelet Analysis

Note : Student can choose any one from DCEC Course as per the availability of the subject teacher/expert. Student may complete the course of his/her choice through MOOC.

GEC courses offered to PG students of other departments only

Course Code	Course name
MA-646(a)	Graph Theory
MA-646(b)	Mathematics for Chemists
MA-646(c)	Mathematical Modelling
MA-647(d)	Bio-Statistics
MA-647(e)	Research Methodology

Note : GEC Courses will be offered only to those students who have studied mathematics upto 10+2 level and as per the availability of subject teacher/expert. Student may complete the course of his/her choice through MOOC.

Course Curriculum

I[st] Semester

Course code	**MA-511**	**Course Name**	**Modern Algebra**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	This course introduces the basic concepts of modern algebra such as groups and rings. The philosophy of this course is that modern algebraic notions play a fundamental role in mathematics itself and in applications to areas such as physics, computer science, economics and engineering.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1:Explain the fundamental concept of groups and its role in modern mathematics and applied contexts. 2: Understand the concept of rings and field of quotients. 3: Better understanding about different domains and field extension. 4.Familiarize with perfect fields, algebraically closed fields and understand the Galois theory of field extension.		

NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting at least one question from each section. All questions carry equal marks.

COURSE SYLLABUS

Units	Content of Each unit
1	Review of basic Group Theory, Conjugacy relation, Normalizer, class equation of a finite group, Direct Product of groups, Sylow's theorems, Sylow p-subgroups, Structure Theorem for finite Abelian groups, Normal and subnormal series, Composition series, Solvable groups, Nilpotent groups, Jordan- Holder theorem(In general survey of groups upto order 15).
2	Review of basic Ring Theory, Ideals, Prime and Maximal Ideals, Quotient rings, Homomorphism, Isomorphism and Automorphism of Rings, Fields of Quotients and embedding theorems, Divisibility in a commutative ring, Principle ideal domain.
3	Concept of H.C.F. and L.C.M. in Integral domain, Euclidean domain, Unique Factorization domain. Extension fields-finite, algebraic and transcendental extensions, Separable and inseparable extensions, Normal extensions.
4	Perfect fields, Finite fields, Primitive elements, Algebraically closed fields. Automorphism of extensions; Fundamental theorem of Galois Theory, Solution of polynomial equations by radicals.

SuggestedReadings:

1. Gallian, J. A. Contemporary Abstract Algebra.9thedition.CengageLearning,2015.
2. Lang, S. Algebra.3rd edition, Springer, 2012.
3. Herstein, I. N. Topics in Algebra. 2nd edition, John Wiley and Sons, 2006.
4. Bhattacharya, P. B. Jain, S. K. and Nagpaul, S. R. Basic Abstract Algebra. 2nd edition, Cambridge University Press, 2003.
5. Khanna,V. K.and Bhammbri,S. K. A Course in Abstract Algebra.Vikas Publishing House, 1999.
6. C, Musili, Introduction to Rings and Modules, Narosa Publishing House, New Delhi (2nd edition), 1994.
7. N.S. Gopalkrishnan, Commutative Algebra, Oxonian Press, New Delhi, 1984

Luther, S. and Passi, I. B. S. Algebra.Vol. I-Groups,Vol.II-Rings, Narosa Publishing House

Course code	MA-512	Course Name	Real Analysis
Programme	M.Sc. Mathematics	Credits	5 (L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The course will develop a deep and rigorous understanding of real line $\mathbb{R}$ and of defining terms to prove the results about convergence and divergence of sequences and series of real numbers. The course will also develop the understanding of Riemann and RS-Integral.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1:Understand about sequences and series and their convergence. 2:Understand Riemann integration theory and Riesz representation theorem. 3: Recognize Riemann-Stieltjes integral and integration of vector valued function. 4:Recognize bounded variation, total variation, directional derivatives, partial derivative and derivative as a linear transformation.		

NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.

COURSE SYLLABUS

Units	Content of Each unit
1	Sequences and series of real valued functions, pointwise convergence, uniformconvergence, Cauchy's criterion and test for uniform convergence of sequence of functions. Tests for uniform convergence of series of functions (Weierstrass's M-test, Abel's test, Dirichlet's test). Uniform convergence versus continuity (Dini'stheorem), integration and differentiation. The Weierstrass approximation theorem.
2	Riemann integration of real valued functions. Existence of the integral. Condition for integrability, properties, integral as a limit of a sum, first mean value theorem,Second mean value theorem. The Riesz representation theorem.
3	Definition and existence of Riemann-Stieltjes integral, Properties of integrals, Integration and differentiation, integration of vector valued function.
4	Function of bounded variation, total variations, function of bounded variations expressed as difference of increasing functions, function of several variables, directional derivatives, partial derivative, derivative as a linear transformation, Inverse and implicit function theorems.

Suggested Readings:

1. Royden, H. L. Real Analysis, MacmillanPub.Co.,Inc. 4th edition, NewYork, 1993.
2. Walter, R. Principles of Mathematical Analysis. 3rd edition, McGraw-Hill, 2017.
3. Apostol,T. M. Mathematical Analysis. 2nd edition.WesleyPublishingCo.2002.
4. P. K. Jain and V. P. Gupta. Lebesgue Measure and Integration. New Age International(P) Ltd., New Delhi, 1986 (Reprint 2000).
5. Simmons,G.F.Introduction to Topology and Modern Analysis. McGraw-Hill Pvt. Ltd. 2016.
6. Walter Rudin, Real and Complex Analysis, McGraw-Hill Book Co., 1966.
7. Kumaresan, S. Topology of Metric Spaces.NarosaPublishingHouse,2011.
8. Terence T. Analysis II. Hindustan Book Agency, 2009.

Course code	**MA-513**	**Course Name**	**Introduction to Topology**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	This course aims to teach the fundamentals of point set topology and Constitute an awareness of need for the topology in Mathematics. It is a central of modern analysis, and many further interesting generalizations of metric space have been developed.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1:Construct metric spaces and understand some general concepts. 2: Concept of Metric topology, Convergence and Completeness of a metric space. 3:Introduction to topological spaces and Kuratowski's closure axioms. 4:Learn the concepts and properties of continuity and homeomorphism.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Definition of a metric space and examples, Open sphere and closed sphere, Neighbourhood, Open sets, Closed sets, Interior points, Closed sets, Limit points and isolated points, Closure of a set, Boundary point.
2	Distance between set and diameter of a set, Subspace of a metric space, Product metric space, Metric topology, Convergence and completeness with examples, Completing a metric space.
3	Definition and examples of topological spaces, Open sets, Closed sets, Interior points, Limit points, Boundary points, exterior points of a set, Frontier points, Closure of a set, Derived set, Kuratowski's closure axioms.
4	Relative topology, Continuity and homeomorphism, Equivalence of homeomorphism, metric topology, Convergence of sequences, Sequential continuity, Open and closed mappings, Bases, Sub-base and local base of a topology.

Suggested Readings:

1. Joshi, K.D. Introduction to General Topology. 2nd edition, New Age International Private Limited, 2017.
2. Munkres, J.R.Toplogy.PearsonEducation,2017.
3. Simmons, G.F. Introduction to Topology and Modern Analysis. Tata McGraw-Hill Education, 2016.
4. Pervin,W.J. Foundations of General Topology. AcademicPress, 2014.
5. Singh,T. B. Elements of Topology. CRC Press, Taylor Francis, 2013.
6. Kelley,J.L.General Topology. 2nd edition, Springer, NewYork, 1991.

Course code	**MA-514**	**Course Name**	**Difference Equations**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to introduce the difference equations, solutions. fundamental theorems for existence and uniqueness difference equations.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the occurring of difference equations and linear difference equations. Also will be able to solve these equations 2: Understand the non-linear difference equations and z-transform. 3: Understand the System of difference equations and finite Fourier analysis. 4. Understand the non-linear difference equations and their systems.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Introduction, Solution of Difference Equation, Solution as Sequences, Linear difference equations of first order, existence and uniqueness of solutions, linear difference equations with constant coefficients, Approximating a Differential Equation by Difference Equation.
2	Equations with variables coefficients, Non-linear equation that can be linearised, The z-transform, Initial Value Theorem, Final Value Theorem, Partial Value Theorem, Stability of linear and non-linear systems, Chaotic behaviour, Asymptotic analysis, Generating Function Technique.
3	Systems of linear difference equations, qualitative behavior of solutions to linear difference equations, Finite Fourier analysis, Non-homogeneous problems, Disconjugacy, Green's Formula, Adjoint Equation, Self Adjoint, The Strum Theory.
4	Nonlinear difference equations (Map), Systems of nonlinear difference equations, Boundary value problems of difference equations, Normal forms, Uniqueness of n characteristic values, Stability criteria for higher order system.

Suggested Readings:

1. Walter G. Kelly and Allen C. Peterson, Difference Equations: An Introduction with Applications, Academic Press, Harcourt Brace Joranovich Publishers, 1991.
2. Calvin Ahlbrandt and Allen C. Peterson, Discrete Hamiltonian System, Difference Equations, Continued fraction and Riccati equations, Kluwer, Bostan, 1996.

Course code	MA-515	Course Name	Optimization Techniques
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of Course	NIL
Course Objective	This course is designed to introduce basic optimization techniques in order to get best results from a set of several possible solutions of different problems viz. Linear programming problems, Transportation problem, Assignment problem and unconstrained and constrained problems etc.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1:Understand Operations Research and its necessity. 2:Understand different techniques to solve linear programming problems and duality. 3:Concept and solution of transportation and assignment problem. 4.Understand network analysis and its concepts.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Introduction to Operations Research, Definition and Scope, Necessity of Operations Research in Industry, Marketing, Agriculture etc., Tools, techniques and methods, Role of OR in decision making.
2	Linear Programming-Simplex Method. Theory of the Simplex Method. Duality and Sensitivity Analysis. Other Algorithms for Linear Programming. Dual Simplex Method. Parametric Linear Programming. Upper Bound Technique, Interior Point Algorithm.
3	Transportation problem and its solution by North-West Corner rule, Row Minima, Column Minima, Matrix Minima, Vogel's Approximation method and Optimum Solution by MODI method; Assignment Problem : Mathematical formulation, Special case of transportation problem, Reduction theorem, Solution by Hungarian method, Travelling Salesman Problem.
4	Network Analysis-Shortest Path problem, Minimum Spanning Tree Problem, Maximum Flow Problem, Minimum Cost Flow Problem, Network Simplex Method. Project Planning and Control with PERT-CPM.

Suggested Readings:

1. F. S. Hiller and G. J. Liberman, Introduction to Operations Research (Sixth Edition), McGraw Hill International Edition, Industrial Engineering Series, 1995 (This book comes with a CD containing tutorial software)
2. G. Hadley, Linear Programming, Narosa Publishing House, 1995.
3. G. Hadley, Non-linear and Dynamic Programming, Addison-Wesley, ReadingMass.
4. Mokhtar, S. Bazaraa, John, J. Jarvis and Hanif, D. Sherali, Linear Programming and Network Flows, John Wiley and Sons, New York, 1990.
5. H. A. Taha, Operations Research : An Introduction, Macmillan Publishing Co. Inc., New York.

Course code	**MA-516**	**Course Name**	**Seminar Presentation and Viva-Voce**
Programme	M.Sc. Mathematics	Credits	5(L-0,T-0,P-10)
Hrs/Week	10	Total Hours	50
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	-	Pre-requisite of course	NIL
Course Objective	The purpose of this course is to enhance communication skills and how to face interviews in competitions.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Will be able to present the subject in interviews. 2: Get ability to face interviews. 3: Skills to present subject in own way.		

NOTE:

1. Viva and Presentation of assigned / selected problem /topic by each student in each of the five papers to be evaluated internally on weekly basis throughout the semester.
   Total Marks : 6x5=30
2. Viva-Voce concerning all the five papers of the semester will be evaluated in the presence of external examiner.
   Total Marks : 70

COURSE SYLLABUS

Units	Content of Each unit
1	The student will have to attend the class regularly and prepare the syllabus of all the five papers taught in a week.

IInd Semester CC Course

Course code	**MA-521**	**Course Name**	**Linear Algebra**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	This course will cover the analysis and implementation of algorithms used to solve linear algebra problems in practice. This course will enable students to acquire further skills in the techniques of linear algebra as well as understanding of the principles underlying the subject.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Explain the fundamental concepts of Linear Algebra such as Vector Spaces & Linear transformation. 2: Understand canonical forms of linear transformation and diagonalization of matrices. 3: Familiarize with module theory and Hilbert Basis Theorem.		
NOTE: Eight questions will be set, atleast two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Vector subspaces, Sum & direct sum of subspaces, Linear span, Linear dependence, independence & properties, Basis, Dimension of Vector Spaces. Finite dimensional Vector spaces, Existence theorem, Extension theorem for bases, Existence of a complementary subspaces of finite dimensional vector space, Quotient space & it's dimension, Linear transformation.
2	Similarity of linear transformations, invariant subspaces, Reduction to triangular forms. Nilpotent transformations, index of Nil-potency, invariant of Nilpotent transformations, Primary decomposition theorem, Jordan Blocks and Jordan forms, Eigen values, eigen vectors and Diagonalization of matrices.
3	Modules, Cyclic modules, Simple modules, Semi-simple modules, Schur's Lemma, Free modules, Noetherian and Artinian modules and Rings. Hilbert basis theorem. Wedderbum-Artin theorem, Uniform modules, Primary modules.

Suggested Readings:

1. N.S. Gopalkrishnan, Commutative Algebra, Oxonian Press, New Delhi, 1984.
2. C, Musili, Introduction to Rings and Modules, Narosa Publishing House, New Delhi (2nd edition) 1994.
3. Vivek Sahai and Vikas Bist, Algebra, Narosa publishing House, New Delhi, 1999.
4. S. Lang, Algebra, (3rd edition), Addison- Wesely, 1993.
5. S. Kumaresan, Linear Algebra: A Geometric Approach, Prentice-Hall of India, 2000.
6. M. Artin, Algebra, Prentice- Hall of India, 1991.
7. Surjeet Singh and Quazi Zameeruddin, Modern Algebra, Vikas Publishing House, New Delhi (7th Edition) 1997.

Course code	**MA-522**	**Course Name**	**Complex Analysis**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to introduce the notion of complex integration and its properties.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the solution of complex integration. 2: Understand the concept of residues and its applications. 3:Understand the bilinear transformation of complex functions. 4. Understand the representation of complex functions as power series and analytic continuation.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Complex integration, Cauchy-Goursat theorem, Cauchy's integral formula. Higher order derivatives, Morera's theorem. Cauchy's inequality and Liouville's theorem. The fundamental theorem of algebra, Taylor's theorem, Maximum modulus principle, Schwarz lemma. Laurent's series, Isolated singularities. Inverse function theorem.
2	Residues, Cauchy's residue theorem, Evaluation of integrals, Branches of many valued functions with special reference to arg z, log z and z^a, Meromorphic functions, Argument principle, Rouche's theorem, Jordan's lemma.
3	Bilinear transformations, their properties and classification. Definition and examples of conformal mappings, Critical points, Transformation $w = z^n, z^2, \sqrt{z}, e^z$.
4	Power series, convergence of power series, Integration and differentiation of power series, Analytic Continuation, Complete Analytic Function, Uniqueness of Analytic Continuation, Schwarz's reflection principle, Riemann zeta function, Montel's theorem.

Suggested Readings:

1. J. B. Conway, Functions of one complex variable. Springer-Verlag, International Student edition, Narosa Publishing House, 1980.
2. L. V. Alhfors, Complex Analysis, McGraw-Hill, 1979.
3. Walter Rudin, Real and Complex Analysis, McGraw-Hill Book Co., 1966.
4. T. Pati, Functions of Complex variable, Pothishala Pvt. Ltd. Allahabad, 1986.
5. S. Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 1997.

Course code	**MA-523**	**Course Name**	**Advanced Topology**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of Course	NIL
Course Objective	The primary objective of this course is to understand the notion of connectedness, compactness and product topology.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the basics of connectedness in topology. 2: Be familiar compact spaces and their properties. 3: Appreciate the richness of Countability axioms and their properties. 4: Familiarize with Urhyson & Tietze theorems and product topology.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Connectedness, connected subsets of the real line, components, Path connectedness, locally connected, locally path connected, Totally disconnected space, Separable spaces.
2	Compactness and its characterizations, Locally compact, countably compact and sequentially compact, Compact subspace of the real line, Compact sets, Finite intersection property, Bolzano-Weierstrass property.
3	Countability : First and second countable spaces, Separation axioms, Lindelof space, T0, T1, T2, Regular and T3 space, Normal and T4 space, Hereditary and Topological properties of these spaces.
4	Urysohn Lemma, Tietze extension theorem, Tychonoff space and T5 space, Compactification, Product topology, Projection mapping.

Suggested Readings:

1. Simmons, G.F. Introduction to Topology and Modern Analysis.McGraw-HillPvt.Ltd.2016.
2. Bachman ,G.and Narici,L. Functional Analysis. Courier Corporation,2012.
3. Conway, J.B. A Course inFunctionalAnalysis.Springer,2010.
4. Kreyszig,E. Introductory Functional Analysis with Applications.JohnWiley,2007.
5. Royden, H.L. Real Analysis. MacMillan PublishingCo.,Inc.,NewYork,4thedition,1993.

Course Code	**MA-524**	**Course Name**	**Tensor Analysis and Elementary Differential Geometry**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of	NIL
Course Objective	In this course, students will be imparted knowledge to enable them to understand several concepts of Tensor Algebra and Differential Geometry such as space curves, surfaces, curvatures, torsion, developables and geodesics.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Learn about the concepts of tensors and its operators. 2: Familiarize with several concepts of Christoffel symbols, gradient, divergence and curl of vectors. 3: Understand the concepts of Euclidean spaces, Frenet-Serret formula and parametric representation of a curve. 4: Understand the several notions of curvatures.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	n-dimensional vector space, co-ordinate systems and their transformation laws, Contravariant and covariant vectors and tensors. Metric tensor and its associate tensor. Mixed tensor, Kronecker deltas. Symmetric and skew-symmetric tensors. Operations on tensors, Process of contraction, Quotient law.
2	Chirstoffel symbols and their co-ordinate transformation laws. Covariant differentiation. Gradient, divergence and curl, Derived vector, tendency of a vector, Theorems related to divergence, Intrinsic derivative.
3	3-dimensional Euclidean space, parametric representation of a curve and a surface, Linear element of a curve. Tangent to a curve, Osculating plane, contact of a surface with a curve, curvature and principal normal, circle of curvature, centre and radius of curvature. Binomial and torsion, plane curve. Frenet-Serret formulae. Helices
4	Locus of centre of Curvature. Osculating sphere, Locus of centre of spherical curvature, involutes and evolutes of a curve. Co-ordinates in terms of arc length parameter, Intrinsic equation of curve.

Suggested Readings:

1. Lal, Bansi and Arora, Sanjay: Three Dimensional Differential Geometry, Atma Ram and Sons, Delhi, 1989.
2. Mishra, R. S.: A course in Tensors with applications to Riemannian Geometry. Pothishala Pvt. Ltd., Allahabad, 1965.
3. Singh, H. D. and Singh, P. K.: Differential Geometry, Ram Prasad & Sons. Agra.
4. Sinha, B. B., Differential Geometry : An Introduction, Shyam Prakashan Mandir, Allahabad, 1978.
5. Weatherburn, C. E. : A Introduction to Tensor Calculus and Reimannian Geometry, Cambridge University Press, London, 1942 and Radha Publishing House, Calcutta (Indian Edn., 1995).
6. Eisenhart, L. P., Differential Geometry with the use of Tensors, Princeton University Press, New Jersey, 1949.

Course code	**MA-525**	**Course Name**	**Operations Research**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of Course	NIL
Course Objective	The course will develop a deep and rigorous understanding of Dynamic programming, Game theory and Integer Programming. These concepts have wide range of applications in real life.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1:Understand many programming problems. 2:Concepts of game theory and solution of games by linear programming. 3:Understand the concepts of Inventory. 4: Understand the applications to Industrial problems and concept of Integer programming and Input-output analysis.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Dynamic Programming, Deterministic and Probabilistic Dynamic Programming, Applications of dynamic programming to a minimal path problem, Linear goal programming, Introduction to non-linear programming.
2	Game Theory : Two-Persons Zero-Sum Games. Games with Mixed Strategies, Graphical Solution. Solution by Linear Programming, Saddle point, Optimal strategy, Value of game, Introduction to Sequencing, Sequencing Problems, Solution to Sequencing Problem - Processing n-jobs through one machine, Processing n-jobs through two machines etc.
3	Inventory system, Direct inventories, Concept of average inventory, Economic ordering quantity, Deterministic inventory Models. Inventory models with price breaks,
4	Integer Programming, Branch and Bound Technique. Applications to Industrial Problems, Optimal Product mix and activity levels. Petroleum refinery operations. Blending problems. Economic Interpretation of dual linear programming problems. Input-Output analysis. Leontief system, Indecomposable and Decomposable Economics.

Suggested Readings:

1. G. Hadley, Non-linear and Dynamic Programming, Addison-Wesley, Reading Mass
2. H. A. Taha, Operations Research : An Introduction. Macmillan Publishing Co. Inc., New York.
3. Kanti Swarup, P. K. Gupta and Man Mohan, Operations Research. Sultan Chand & Sons, New Delhi.
4. S. S. Rao, Optimization Theory and Applications, Wiley Eastern Ltd., New Delhi.
5. Prem Kumar Gupta and D. S. Hua, Operations Research – An Introduction, S. Chand & Company Ltd., New Delhi.

Course code	**MA-526**	**Course Name**	**Powerpoint Presentation and Viva-Voce**
Programme	M.Sc. Mathematics	Credits	5(L-0,T-0,P-10)
Hrs/Week	10	Total Hours	50
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	-	Pre-requisite of Course	NIL
Course Objective	The purpose of this course is to enhance communication skills and how to face interviews in competitions.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Will be able to present the subject in interviews. 2: Get ability to face interviews. 3: Skills to prepare presentation on Powerpoint.		

COURSE SYLLABUS

Units	Content of Each unit
1	A : Viva and Presentation of assigned / selected problem /topic using PPT by each student in each of the other five papers to be evaluated internally throughout the semester. Total Marks : 6x5=30
2	B :Viva –Voce concerning all other five papers of the semester to be evaluated externally Total Marks : 70

SEMESTER-III

Course code	**MA-631**	**Course Name**	**Functional Analysis**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of Course	NIL
Course Objective	To familiarize with the basic tools of Functional Analysis involving normed spaces, Banach spaces and Hilbert spaces, their properties dependent on the dimension and the bounded linear operators from one space to another.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Concepts of metric spaces, Cauchy sequences, Normed and Banach spaces. 2. Computing dual spaces and introduction to Hilbert spaces. 3. Understand different concepts of Hilbert spaces and weak and strong convergence. 4. Familiarize with Hahn-Banach theorem, its applications, projections and closed graph theorem.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Metric Space, sequences, Cauchy sequences, complete metric spaces and examples, Banach fixed point principle, normed linear spaces. Quotient space, Equivalent norms, Banach spaces, examples of Banach spaces and subspaces.
2	Continuity of linear maps, Equivalent norms, normed spaces of bounded linear maps, bounded linear functionals, dual spaces of $l\ p$, $\mathbb{R}n$ and reflexivity, Inner product spaces, Hilbert spaces and examples, orthogonality, orthonormal sets, Bessel's inequality, Parseval's theorem, the conjugate space of a Hilbert space., Riesz lemma.
3	Representation of bounded functional on Hilbert space, adjoint operators, self adjoint operators, normal and unitary operators, weak and strong convergence, completely continuous operators.
4	Hahn-Banach theorem and its applications, uniform boundedness principle, open mapping theorem, projections on Banach spaces, closed graph theorem.

Suggested Readings:

1. Bachman, G. and Narici, L. Functional Analysis. Courier Corporation, 2012.
2. Conway, J. B. A Course in Functional Analysis. Springer, 2010.
3. Kreyszig, E. Introductory Functional Analysis with Applications. John Wiley, 2007.
4. G. Bachman and L. Narici, Functional Analysis, Academic Pres, 1966.
5. C. Goffman and G. Pedrick, First Course in Functional Analysis, Prentice Hall of India, New Delhi, 1987.

Course code	**MA-632**	**Course Name**	**Basic Statistics**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of Course	NIL
Course Objective	The objective of this course is to introduce the basic concepts of statistics which finds many applications across a number of fields.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the concept of set theoretic probability. 2: Understand the use of random variable and probability functions. 3:Understand the concept of Mathematical expectation, Moment generating function, Characteristic function and Law of large numbers. 4. Understand the concept of hypothesis and its testing.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Probability- Set theoretic approach, Boole's inequality, Baye's theorem, Geometric probability, Law of total probability, Addition and Multiplication theorem.
2	Random Variables-Distribution function, Joint probability distribution function, Conditional distribution function, Transformation of one and two dimensional Random variables.
3	Mathematical Expectation- Covariance, variance of n variates, Tchebycheffs Inequality, Weak and strong Laws of large numbers, Moment Generating and Characteristic Functions and Cumulants- Central Limit theorem, Lindeberg-Levy theorem.
4	Theory of sampling and its objective, Types of population, Null hypothesis and Alternative hypothesis, Data collection, Level of significance, Procedure for testing a hypothesis.

Suggested Readings:

1. J. Medhi; Statistical Methods, New age International (P)Ltd.
2. A.J. Medhi Festschrift: Prob. &Models and Statistics, New Age International (P) Ltd.
3. Hogg (Reprint ISBN-8178086301): Introduction of Mathematical Statistics, Pearson Education.
4. J.K. Ghosh, Mathematical Statistics, John Wiley & Sons, New York.
5. J.K. Goyal & J.N. Sharma, Mathematical Statistics.
6. M.Ray& H.S. Sharma, Mathematical Statistics, Ram Prasad &Sons.
7. Gupta and Kapoor, Mathematical Statistics , S.Chand, New Delhi.
8. Goon, Gupta, Dasgupta, Fundamental of Mathematical Statistics and Applied Statistics.

Course Code	**MA-633**	**Course Name**	**Fluid Dynamics**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to provide a treatment of topics in fluid dynamics to a standard where the student will be able to apply the techniques used in deriving a range of important results and in research problems. The objective is to provide the student with knowledge of the fundamentals of fluid dynamics and an appreciation of their application to real world problems.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the basic principles of fluid dynamics and equation of continuity. 2: Familiarize with the concept of equation of motion. 3: Analyze irrotational and rotational flows in fluids, some of their properties and Blasius theorem. 4: Find analytical solution of Navier Stoke equation and solutions of some benchmark problems		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Kinematics - Lagrangian and Eulerian methods. Equation of continuity in different forms, Boundary surfaces. Stream lines, Path lines and stream lines. Velocity potential. Irrotational and rotational motions. Vortex lines.
2	Equations of motion – Lagrange's and Euler's equations of motion. Bernoulli's Theorem.Equation of motion by flux method. Equations referred to moving axes. Impulsive action.
3	Stream function. Irrotational motion in two-dimensions. Complex velocity potential Sources, sinks, doublets and their images. Conformal mapping. Milne-Thomson circle Theorem, Blasius theorem.
4	Two-dimensional irrotational method produced by motion or circular, co-axial and elliptic cylinders in an infinite mass of liquid. Kinetic energy of liquid. Motion of a sphere through a liquid at rest at infinity. Liquid streaming past a fixed sphere. Equation of motion of a sphere. Stoke's stream function. Introduction of vortex and wave motions.

Suggested Readings:

1. A. S. Ramsey, Dynamics Part II, The English Language Book Society and Cambridge University Press, 1972.
2. F. Chorlton, Text book of fluid Dynamics, C. B. S. Publishers, Delhi, 1985.
3. G. K. Batchelor, An Introduction to Fluid Mechanics, Foundation Books, New Delhi, 1994.
4. L. D. Landau and E. M. Lipschitz, Fluid Mechanics, Pergamon Press, London, 1985.
5. S. W. Yuan, Foundations of Fluid Mechanics. Prentice Hall of India, Pvt. Ltd., New Delhi, 1976.

Course code	**MA-634**	**Course Name**	**Differential Equations**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of Course	NIL
Course Objective	The objective of this course is to introduce the theory of ordinary differential equations, fundamental theorems for existence and uniqueness differential equations (DE's).		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the theory of ordinary differential equations of various types, fundamental concepts of existence of solutions. 2: Familiarize with concept of Continuation of solutions and IVPs. 3: Understand the differential inequalities and maximal and minimal solutions. 4. Understand the series solution of different types of differential equations.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Lipschitz Condition, Uniform Boundedness, Equi-continuity, Differential Equations, Initial Value Problem and Equivalent Integral Equation, System of Differential Equations, Vector Notation of Differential Equations, m th Order Differential Equation in n-dimensions, Concept of Existence, Ascoli-Aerzela Theorem.
2	A theorem of convergence of solutions of a family of initial value problems, Picard's Theorem, Picard's Second Theorem, Picard-Lindelof Theorem, Existence and uniqueness theory, Cauchy Peano's Theorem, The Gronwall's Inequality, Theorem of Wintner, Kamke's Uniqueness Theorem, Nagumo's Criteria, Osgood's Criteria, Successive Approximations.
3	Strum theory in linear second order ODEs, Adjoint Differential Equation, Abel's Formula,Orthogonal and Orthonormal Functions, Gram–Schmidt Process of Orthogonalization, Strum-Liouville's Problems, Eigen Values and Eigen Functions, Strum – Liouville's Problem, Eigen Values of Strum – Liouville's Problem.
4	Series solution of second order linear differential equations near ordinary point. Singularity and the solution in the neighborhood of regular singular point. Euler equation and Frobenius method, solution of Legendre, Bessel, Hypergeometric, Hermite and Laguerre differential equations.

Suggested Readings:

1.Reid, W. T. Ordinary Differential Equations. John Wiley and Sons, New York, 1971.
2. Simmons, G. F. Differential Equations with Applications and Historical Notes. 2nd edition, Tata McGraw Hill, New Delhi, 2016.
3. Ross, S. L. Differential Equations. 3rd edition, Wiley India, 2007.
4. Raisinghania, M. D. Advanced Differential Equations. S. Chand & Company Ltd., New Delhi, 2001.
5. P. Hartman, Ordinary Differential Equations, John Wiley, 1964.
6. E.A Coddington and N. Levinson, Theory of ordinary differential equations, McGraw Hill, NY, 1955.

Course code	**MA-635**	**Course Name**	**Project/Dissertation**
Programme	M.Sc. Mathematics	Credits	5(L-0,T-0,P-10)
Hrs/Week	10	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	-	Pre-requisite of course	NIL
Course Objective	The purpose of this course is to enhance writing and communication skills and how to present subject and ongoing researches.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Will be able to present research work in the field. 2: Get ability to write subject in own way. 3: Skills to know future of the subject. 4: Get knowledge of preparing Proposal/Synopsis.		

NOTE:

1. Internal evaluation of the Proposal/Synopsis will be on the basis of two periodic presentations before the final submission of his/her proposal. Each presentation will be evaluated in 15 marks.
2. The final Proposal/Synopsis submitted by the student will be evaluated by the external examiner through his/her Presentation/Viva-Voce.

COURSE SYLLABUS

Units	Content of Each unit
1	The student will have to collect the matter on any one topic of his interest from the courses running in the Mathematics Department at P.G. level from the books/e-resources/library and express his/her view in his/her own way and will have to submit a brief summary in the form of Proposal/Synopsis duly typed before the End-Sem. Examination of the 3rd Semester.

MOOC/DCEC Courses offered for M.Sc. (Mathematics) students only

Course code	**MA-636(a)**	**Course Name**	**Advanced Differential Geometry**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	In this course, students will be imparted knowledge to enable them to understand several concepts of Differential Geometry such as space curves, surfaces, curvatures, torsion, developables and geodesics.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Familiarize with various forms of surfaces and concepts of tangent plane and developables. 2. Learn about orthogonality and parallelism of two directions and fundamental magnitudes of first and second order. 3. Understand about principle curvature, catenoids and parametric curves. 4. Concept of Geodesics and its curvature.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Various forms of a surface, explicit form. Gaussian and Monge's forms. Different types of surfaces, right helicoid, conicoid, surface of revolution; Tangent plane to a surface. One parameter family of surfaces, their characteristic curve and envelope. Ruled surfaces; Developable and skew-surfaces, properties of developable. Developable associated with space-curves.
2	Curvilinear co-ordinates. Fundamental magnitudes of first order. Christoffel symbols. Direction on a surface. Angle between two directions. Orthogonality and parallelism of two directions determined by a quardratic equation. Inclinations of direction with parametric curves. Normal to a surface. Fundamental magnitudes of second order. Derivatives of unit normal to a surface.
3	Normal and oblique sections of a surface and their curvatures. Meusnier's theorem, Normal curvature. Principal curvatures. Principal directions, First and second curvatures. Minimal surface. Umbilic point and umbilical surfaces. Lines of curvatures. Joachimsthal's theorem. Rodrigues formula. Parametric curves as lines of curvature. Euler's formula for normal curvature, Catenoid as the only real minimal surface of revolution. Developables associated with lines of curvature.
4	Asymptotic lines, Beltrami-Enneper's theorems. Curvature of asymptotic lines. Geodesics, Euler-Lagrange conditions. Differential equations of geodesics. Existence theorem. Properties of geodesics. Parametric curves as geodesics. Torsion of a geodesic, Bonnet's theorem, Joachimsthal's theorem. Geodesic curvature of curve.

Suggested Readings:

. Weatherburn, C.E.Differential Geometry of Three Dimensions, Cambridge University Press, 2016.

2. Graustein, W.C. Differential Geometry. Courier Corporation,2012.

3. Wilmore T.J. An Introduction to Differential Geometry, Dover PublicationsInc.,2012.

Pressley, A. Elementary Differential Geometry. Springer,2002.

Course code	**MA-636(b)**	**Course Name**	**Measure Theory and Integration**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	Measure theory provides a foundation for many branches of mathematics such as harmonic analysis, ergodic theory, theory of partial differential equations and probability theory. It is a central, extremely useful part of modern analysis, and many further interesting generalizations of measure theory have been developed.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Use the concepts of measurable set and measurable function. 2: Familiarize with some properties of measures. 3: State and explain the construction of the Lebesgue integral and use it. 4: Apply the theorems of monotone and dominated convergence and Fatou's lemma.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Length of an open set, concept of measure, Lebesgue outer measure and measurable sets, example of non-measurable set, Sigma algebra, Borel sets, and – sets, Outer and inner regularity of Lebesgue measure.
2	Set function, abstract measure spaces, properties of measures, some examples of measures, measurable spaces, measurable functions, combinations of measurable functions, and limits of measurable functions.
3	Review of Riemann integral, Integrable simple functions, the Lebesgue integration of a measurable function, Iintegration with respect to a measure.
4	Almost everywhere convergence, Convergence in measure, Fatou's Lemma, monotone and dominated convergence theorems.

Suggested Readings:

1. Berberian, S. K. Measure and Integration. AMS Chelsea Publications, 2011.
2. Royden, H. L. and Fitzpatrick P. M. Real Analysis. 4th edition, Pearson India, 2010.
3. Barra, G. de. Measure Theory and Integration. New Age International (P) Ltd., 2009.
4. Rana, I. K. An Introduction to Measure and Integration. 2nd edition, Narosa Publishing House, 2004.
5. Folland, G. B. Real Analysis. John Wiley & Sons, Inc., New York, 1999.
6. Hewitt, E. and Stromberg, K. Real and Abstract Analysis. Springer-Verlag, New York, 1975.

Course code	**MA-636(c)**	**Course Name**	**Mathematics for Finance and Insurance**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	This course introduces the basic concepts of Financial Management such as Insurance and Measurement of returns under uncertainty situations. The philosophy of this course is that Time value of Money - Interest rate and discount rate play a fundamental role in Life Insurance Mathematics – Construction of Morality Tables		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Demonstrate knowledge of the terminology related to nature, scope, goals, risks and decisions of financial management. 2: Predict various types of returns and risks in investments and take necessary protective measures for minimizing the risk. 3: Develop ability to understand, analyze and solve problems in bonds, finance and insurance. 4: Build skills for computation of premium of life insurance and claims for general insurance using probability distributions		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Financial Management –overview. Nature and scope of financial management. Goals and main decisions of financial management. Difference between risk, Speculation and gambling. Time value of Money - Interest rate and discount rate. Present value and future value discrete case as well as continuous compounding case. Annuities and its kinds.
2	Meaning of return. Return as Internal Rate of Return (IRR). Numerical methods like Newton Raphson method to calculate IRR. Measurement of returns under uncertainty situations. Meaning of risk. Difference between risk and uncertainty. Types of risks. Measurements of risk. Calculation of security and Portfolio Risk and Return-Markowitz Model. Sharpe Single Index Model Systematic Risk and Unsystematic Risk.
3	Taylor series and Bond Valuation. Calculation of Duration and Convexity of bonds. Insurance Fundamentals – Insurance defined. Meaning of loss. Chances of loss, Peril, Hazard, proximate cause in insurance. Costs and benefits of insurance to the society and branches of insurance-life insurance and various types of general insurance. Insurable loss exposures- feature of a loss that is ideal for insurance.
4	Life Insurance Mathematics – Construction of Morality Tables. Computation of Premium of Life Insurance for a fixed duration and for the whole life. Determination of claims for General Insurance – Using Poisson Distribution and Negative Binomial Distribution –the Polya Case. Determination of the amount of Claims of General Insurance – Compound Aggregate claim model and its properties, Claims of reinsurance. Calculation of a compound claim density function F, Recursive and approximate formulae for F.

Suggested Readings:
1. Ross, S. M. An Introduction to Mathematical Finance. Cambridge University Press, 2019.
2. Elliott, R. J. and Kopp, P. E. Mathematics of Financial Markets. Sprigner Verlag, New York Inc, 2018.
3. Damodaran, A. Corporate Finance - Theory and Practice. John Wiley & Sons, Inc, 2012.
4. Hull, J. C. Options, Futures, and Other Derivatives. Prentice-Hall of India Private Ltd, 2010.

Course code	**MA-636(d)**	**Course Name**	**Integral Equations**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	In this course we study in detail about integral equations and calculus of variations. Integral equations find numerous applications in real life physical problems. The main objective of the course is to make the learner familiarize with resolvent kernel, successive approximation, solution of homogeneous Fredholm integral equation for solving integral equations and variational problems. Differential equations can be studied for their solutions by transforming them into integro-differential equations using Laplace transform.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Familiarize with various kinds of integral equations and some methods of approximations. 2: Find the solutions of Volterra Integral equations using Neumann series method. 3: Understand the classical Fredholm theory. 4: Understanding of Hilbert Schmidt theorem and solutions by using symmetric kernels.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Definition of integral Equations and their classification. Eigen values and Eigen functions, Fredholm integral equations of second kind with separable kernels. Reduction to a system of algebraic equations. An approximate method, method of Successive Approximations, Iterative scheme for Fredholm integral equations of the second kind.
2	Conditions of uniform convergence and uniqueness of series solution. Resolvent kernel and its results. Application of iterative scheme to Volterra integral equations of the second kind.
3	Classical Fredholm theory, Fredholm Theorems, Questions based on Fredholm first fundamental theorem, Symmetric kernels, complex Hilbert space. Orthonormal system of functions.
4	Fundamental properties of eigen values and eigen functions for Symmetric kernels. Expansion in eigen function and bilinear form. Hilbert-Schmidt theorem and some immediate consequences. Solutions of integral equations with symmetric Kernels.

Suggested Readings:

1. R.P. Kanwal, Linear Integral Equation - Theory and Techniques, Academic Press, New York. 1971.
2. S.G. Mikhlin, Linear Integral Equations (Translated from Russian) Hindustan Book Agency,1960.
3. William Vernon Lovitt, Linear Integral Equations.

Course code	**MA-636(e)**	**Course Name**	**Bio-mechanics**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	This course will introduce students to the mechanical principles that can be applied to human structure and function allowing analysus of human movement and the musculoskeletal system.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand foundations of motion of fluid and engineering of blood vessels. 2. Understand laws of thermodynamics and tissue engineering of skin. 3. Concept of indicator dilution method and biomechanical aspects of growth.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Newton's equation of motion, Segmental movement and vibrations, Fluid Dynamic forces acting on moving bodies, Blood flow in heart, lung, arteries and veins, Micro and macrocirculation, Engineering of blood vessels.
2	Respiratory gas flow, The laws of thermodynamics, Molecular diffusion, Mechanisms in Membranes and multiphasic structure, Stress, strain and stability of organs, Tissue Engineering of skin.
3	Mass Transport in capillaries, tissues, interstitial space, Lymphatics, Indicator dilution method and Peristalsis, Description of Internal deformation and forces, Strength, trauma and tolerance, Biomechanical aspects of growth.

Suggested Readings:

1. D. Knudson, Fundamentals of Biomechanics, Springer Publication, 2007.
2. S.J. Hall, Basic Biomechanics, McGraw Hill Edition.
3. Y. C. Fung, Biomechanics, Springer Publication, 1993.
4. S. Koley, Textbook of Biomechanics, AITBS Publishers, India.

SEEC (Skill Enhancement Elective Course, non-credit, only qualifying in nature)

Course code	**MA-637(a)**	**Course Name**	**Programming in MATLAB**
Programme	M.Sc. Mathematics	Credits	0(L-4,T-1,P-2)
Hrs/Week	4	Total Hours	40
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The course objective is to familiarize the students with problem solving through MATLAB. The course aims to give exposure to basic concepts of the MATLAB programming. The course aims to design the MATLAB programs for various numerical methods.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Overview and display format of MATLAB programs 2: Acquire knowledge of various elementary built-in functions, data types and Matrix operations 3: Application of MATLAB in numerical methods. 4: Write MATLAB programs for various numerical methods use to solve nonlinear equations, system of linear equations, interpolation, numerical differentiation and integrations, differential equations		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Overview of MATLAB, operators, display format, elementary built-in functions, working with variables, general commands, data types, data import, arrays, operations with arrays.
2	Matrices: eigenvalues and eigenvectors, similarity transformation and diagonalization, functions, script files, operators, loops and conditional statements, programming in MATLAB, graphics- 2-D and 3-D plots, input and output.
3	Applications in numerical methods: bisection method, false position (RegulaFalsi) method, Newton–Raphson) method System of linear equations, LU decomposition, Gauss elimination method, Gauss Seidel method, Gauss Jordan method, interpolation, Lagrange and Newton polynomials.
4	Applications to numerical differentiation and integrations: Trapezoidal method and Simpson method, Runge–Kutta method, introduction to working with modules in MATLAB.

Suggested Readings:

1. Kumar, S. S. and Lenina, S. V. B. Matlab: Easy Way of Learning. PHI Learning Pvt. Ltd., 2016.
2. Pratap, R. Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers. Oxford University Press, 2016.
3. Chapman, S. J. Matlab Programming for Engineers, 5th edition, Cengage Learning, 2015.
4. Otto, S.R. and Denier, J.P. An Introduction to Programming and Numerical Methods in MATLAB. Springer-Verlag, 2005.
5. Yang, W. Y., Cao, W., Chung, T. and Morris, J. Applied Numerical Methods using MATLAB. John Wiley Inderscience, 2005.
6. Getting Started with MATLAB, Maths Works Inc. www. in.mathsworks.com.

Course code	**MA-637(b)**	**Course Name**	**Programming in SCILAB**
Programme	M.Sc. Mathematics	Credits	0(L-1,T-1,P-2)
Hrs/Week	4	Total Hours	40
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The course objective is to familiarize the students with problem solving through SCILAB. The course aims to give exposure to basic concepts of the SCILAB programming. The course aims to design the SCILAB programs for various numerical methods.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Overview and display format of SCILAB programs 2: Acquire knowledge of SCILAB and basic elements of the language. 3: Learn about Matrix in SCILAB 4: Write SCILAB programs using loops and plotting of functions in 2D and types of statements.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Overview of SCILAB, operators, display format, elementary built-in functions, working with variables, general commands, data types, data import, arrays, operations with arrays.
2	Getting started, The console, The editor, Docking, Using exec, Batch processing, Basic elements of the language, Creating real variables, Variable name, Comments and continuation lines, Elementary mathematical functions, Booleans, Complex numbers, Strings Dynamic type of variables,
3	Matrices, Overview, Create a matrix of real values, The empty matrix, Query matrices, Accessing the elements of a matrix, The colon ":" operator, The dollar "$" operator, Low-level operations, Element-wise operations, Higher level linear algebra features.
4	Looping and branching, The if statement, The select statement, The for statement, The while statement, Functions, Defining a function, Function libraries, Managing output arguments, Plotting, 2D plot Titles, axis and legends, Export.

Suggested Readings:

1.https://mars.uta.edu/mae3183/simulation/introscilab_baudin.pdf
2.https://www.scilab.org/sites/default/files/Scilab_beginners.pdf
3. https://www.scilab.org/sites/default/files/progscilab-v.0.10_en.pdf

Course code	**MA-637(c)**	**Course Name**	**Artificial Intelligence and Machine Learning**
Programme	M.Sc. Mathematics	Credits	0(L-1,T-1,P-2)
Hrs/Week	4	Total Hours	40
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	In this course, the students prepare their career in Computer Science and Engineering where knowledge of AI and ML techniques leading to the advancement of research and technology.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the concept of Artificial Intelligence. 2: Apply the aspect of AI in healthcare industry, manufacturing, education sector etc. 3: Familiarize with Knowledge based AI systems and approaches 4: Recognize the concepts of Machine Learning and identify the neutral networks and NLP in designing AI models.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	History of artificial intelligence, The birth of artificial intelligence, AI Winters, Todays' AI, Historical milestones in the development of AI, Great contributors, People who have influenced AI , Differences between strong AI and weak AI, Artificial Intelligence definitions, Emergence of AI – Technological advances.
2	Machine Learning ---> Deep Learning --->AI, Functions of AI, Characteristics of artificial intelligence, Applications of AI, AI in health care, Industry 4.0, AI in manufacturing, AI in education sector, AI in business, AI in Finance Sector, AI in Law, AI in society, Cognitive science and AI, Cognition and process of Cognition, Disciplines in Cognitive science, Multidisciplinary subject, Linguistics, Artificial intelligence as Cognitive science, Methods in Cognitive science, Watson.
3	Introduction to knowledge representation systems, Knowledge representation using logic, Propositional logic, Semantics of propositional logic, Properties of propositional logic statements, Tautologies and logical implication, Resolution, Conjunctive normal form, Resolution is valid, Resolution algorithm, Knowledgebase systems, Structure of a knowledge based system.
4	Components of expert systems, Expert systems development, Wumpus world, Logic, A simple knowledge base, Exploring the Wumpus world, Semantic net, Inference in semantic networks, Semantic networks: Types and components, Types of relationships in semantic network, Frames, Frames: Some examples, Non-monotonic logic, Circumscription, Default logic, Artificial Neural Network, Natural language processing, Classical NLP, Feed-forward networks, Recurrent neural networks and recursive networks, Features for NLP problems, Framenet Vs. Wordnet, Features for text, Features for word relations, NGRAM features.

Suggested Readings:
1. Gersting, J. L. Mathematical Structures for Computer Science. 7th edition, Computer Science Press, New York, 2020.
2. Markiewicz, M. and Zheng, J. Getting Started with Artificial Intelligence: A Practical Guide to Building Enterprise. Ist edition, Shroff/O'Reilly, 2019.
3. Theobald, O. Machine Learning: Make Your Own Recommender System. Scatterplot Press, 2018.
4. Flasinski, M. Introduction to Artificial Intelligence. Springer, 2017.

Course code	**MA-637(d)**	**Course Name**	**Programming in C**
Programme	M.Sc. Mathematics	Credits	0(L-1,T-1,P-2)
Hrs/Week	4	Total Hours	40
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The course objective is to familiarize the students with problem solving through C programming. The course aims to give exposure to basic concepts of the C programming. The lab component of this course is designed to provide hands on-training with the concepts.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Classify and overview the programming languages and develop basic C programs, to define data types and use them in simple data processing 2: Use various C-operators, expressions and input/output statements 3: Understand control flow using conditional branching and loop structures and the concept of array in problem solving 4: Interprets the concepts of pointers, and classify functions and their usage		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	An overview of programming, programming languages, classification, C essentials program development, anatomy of a C function, variables, constants, expressions, assignment statements, formatting source files, continuation character, the preprocessor, scalar data types-declarations, different types of integers, different kinds of integer constants, floating point types, initialization, mixing types, explicit conversions-casts, data types
2	Operators and expressions - precedence and associatively, unary plus and minus operators, binary arithmetic operators, arithmetic assignment operators, increment and decrement operators, comma operator, relational operators, logical operators, bit manipulation operators, bitwise assignment operators, cast operator, size of operators, conditional operator, memory operators, input/output functions.
3	Control Flow - conditional branching, the switch statement, looping, nested loops, break and continue statements, goto statement, infinite loops, Arrays - declaring an array, arrays and memory, initializing arrays, encryption and decryption, multidimensional arrays, strings.
4	Functions - passing arguments, declarations and calls, recursion, the main ( ) function, passing arrays as function arguments. Pointers - pointer arithmetic, accessing array elements through pointers, passing pointers as function arguments, arrays of pointers.

Suggested Readings:

1. Balagurusamy, E. Programming in ANSI C. 3rdedition. TATA McGraw Hill, 2016.
2. Brain W. K. and Ritchie D. M. C Programme Language. 2 nd edition, Pearson, 2015.
3. Darnell, P. A. and Margolis, P. E. C: A Software Engineering Approach. Narosa Publishing, House (Springer International Student Edition), 2012.
4. Yashavant, P. K. Let Us C. BPB Publication, 2008.
5. Byrons, G. Programming With C. 2nd edition, Schaum's Series, 1996.

Course code	**MA-637(e)**	**Course Name**	**Research Methodology**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	Demonstrate the ability to choose methods appropriate to research aims and objectives. Understand the limitations of particular research methods. Develop skills in qualitative and quantitative data analysis and presentation. Develop advanced critical thinking skills.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand foundations of research and its characteristics. 2. Identify problems and testing of hypothesis. 3. Designing research and understanding experimental design. 4.Understand different approachs of research.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Foundations of Research: Meaning, Objectives, Motivation, Utility. Concept of theory, empiricism, deductive and inductive theory. Characteristics of scientific method – Understanding the language of research – Concept, Construct, Definition, Variable. Research Process
2	Problem Identification & Formulation – Research Question – Investigation Question – Measurement Issues – Hypothesis – Qualities of a good Hypothesis – Null Hypothesis & Alternative Hypothesis. Hypothesis Testing – Logic & Importance.
3	Research Design: Concept and Importance in Research – Features of a good research design – Exploratory Research Design – concept, types and uses, Descriptive Research Designs – concept, types and uses. Experimental Design: Concept of Independent & Dependent variables.
4	Qualitative and Quantitative Research: Qualitative research – Quantitative research – Concept of measurement, causality, generalization, replication. Merging the two approaches.

Suggested Readings:

1. R.P. Kanwal, Linear Integral Equation - Theory and Techniques, Academic Press, New York. 1971.
2. S.G. Mikhlin, Linear Integral Equations (Translated from Russian) Hindustan Book Agency,1960.
3. William Vernon Lovitt, Linear Integral Equations.

SEMESTER-IV

Course code	**MA-641**	**Course Name**	**Advanced Partial Differential Equations with Applications**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to introduce the theory of ordinary differential equations, fundamental theorems for existence and uniqueness of differential equations (DE's).		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Get an idea about First order PDEs, Classification of second order PDEs and their reduction to Canonical form. 2: Understand non-linear first order PDEs and Hamilton-Jacobi equations. 3:Understand the conservation laws, Entropy condition and Traffic law problems. 4. Familiarize with solutions of Heat, Wave and Laplace equations.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	First order equations, Classification of second order PDE, canonical form second order linear equations with constant coefficients, method of separation of variables. Characteristics and uniqueness theorems, Elliptic and Parabolic partial differential equations.
2	Non-linear First Order PDEs: Complete Integrals, Envelopes or Singular Integrals, Characteristics, Hamilton-Jacobi Equations (Characteristic for the Hamilton-Jacobi Equation, Calculus of Variations, Hamilton's ODEs, Legendre's Transform, HopfLax Formula, Weak Solution, Uniqueness).
3	Conservation Laws (Weak Solution, Strong Solution, Integral Solution for a General Conservation Law, Rankine Hugoniot Condition, Rarefaction Waves and Non-physical Shocks, Entropy Condition, Lax-Oleinik Formula, Another Entropy Condition, Riemann's Problem, Long Time behavior), Traffic Flow problems.
4	Boundary Value problems, Derivation of Heat, Wave and Laplace equations in dimension, two dimension and three dimension, Their solution by Methods of separation of variables in Cartesian, Cylindrical and Spherical polar Co-ordinate Systems.

Suggested Readings:

1. T. Amarnath, An Elementary Course in Partial Differential Equations ,Narosa Publishing Company, 1997.
2. Phoolan Prasad and Renuka Ravindran, Partial Differential Equations, Wiley-Eastern Ltd, 1985.
3. Lokenath Debnath and Dambaru Bhatta , Integral Transforms and Their Applications, Chapman & Hall/CRC; 2 edition, 2006.
4. Tyn Myint-U: Partial differential equations for scientists and engineers, 3rd ed. North Holland, 1989.
5. IN. Sneddon, Special Functions.

Course code	**MA-642**	**Course Name**	**Advanced Mathematical Statistics**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of Course	NIL
Course Objective	The aim of the course is to enable the students with understanding of various types of measures, various types of probability distributions and testing of hypothesis problems. It aims to equip the students with standard concepts of statistical techniques and their utilization.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Explore the basic ideas about different distributions. 2: Understand the concept of significance and Chi-square distribution. 3: Familiarize with the concept of ANOVA.		
NOTE: Eight questions will be set, atleast two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Distributions relationship with each other, distribution of their sum, difference, product, quotient etc. (a) Binomial, Poisson, Negative Binomial, Geometric, Pascal's Polya's Hypergeometric distributions, Multinomial power series and discrete uniform, compound binomial and Poisson distributions.
2	Normal, log-normal, Gamma, Beta, Exponential, Bivariate Normal, Laplace, Weibul, Cauchy and Pearson's distributions, Derivation of Chi-square distributions, Non central chi-square distribution.Test of significance. Distribution Function-of t. F and z test of significance.
3	Theory of estimation principle of maximum likelihood, properties of maximum likelihood estimators. Analysis of variance - Analysis of variance in one way and two ways classification.

Suggested Readings:

1. J. Medhi; Statistical Methods, New age International (P)Ltd.
2. A. J. Medhi Festschrift: Prob. &Models and Statistics, New Age International (P) Ltd.
3. Hogg (Reprint ISBN-8178086301): Introduction of Mathematical Statistics, Pearson Education.
4. J.K. Ghosh, Mathematical Statistics, John Wiley & Sons, New York.
5. J.K. Goyal & J.N. Sharma, Mathematical Statistics.
6. M. Ray & H.S. Sharma, Mathematical Statistics, Ram Prasad &Sons.
7. Gupta and Kapoor, Mathematical Statistics , S.Chand, New Delhi.
8. Goon, Gupta, Dasgupta, Fundamental of Mathematical Statistics and Applied Statistics.

Course Code	**MA-643**	**Course Name**	**Advanced Discrete Mathematics**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The main objective of the course is to introduce concepts of mathematical logic, Lattice and graph theory and to give a brief introduction of Boolean algebra, bipartite graphs and trees and studying for their applications in real life.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the concept of lattice. 2: Analyze logical propositions using truth tables and the applications of Boolean algebra in switching theory. 3: Use the concept of planar graphs, trees and study for their properties. 4: Understand the concept of paths and circuits.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Lattices – Lattices as partially ordered sets. Their properties. Lattices as Algebraic systems. Sublattices, Direct products, and Homomorphisms. Some Special lattices e.g., Complete, Complemented and Distributive Lattices.
2	Boolean Algebras – Boolean Algebras as lattices. Various Boolean Identities. The Switching Algebra example. Sub algebras, Direct Products and Homomorphisms. Join irreducible elements, Atoms and Minterms. Boolean Forms and their Equivalence. Minterm Boolean Forms, Sum of Products. Canonical Forms. Minimization of Boolean Functions. Applications of Boolean Algebra to Switching Theory (using AND, OR and NOT gates). The Karnaugh Map method.
3	Definition of (undirected) Graphs Paths, Circuits; Cycles, and Subgraphs. Induced Subgraphs. Degree of a vertex. Connectivity. Planar Graphs and their properties. Trees, Euler's Formula for connected Planar Graphs. Complete and Complete Bipartite Graphs. Kuratowski's Theorem (statement only) and its use. Spanning Trees, Cut-sets, Fundamental Cut-sets, and Cycles, Minimal Spanning Trees and Kruskal's Algorithm. Matrix Representations of Graphs.
4	Euler's Theorem on the Existence of Eulerian Paths and Circuits. Directed Graphs. In degree and Out degree of a vertex. Weighted undirected Graphs. Dijkstra's Algorithm. Strong Connectivity and Warshall's Algorithm. Directed Trees. Search Trees. Tree Traversals.

Suggested Readings:

1. J.P. Tremblay & R. Manohar, Discrete Mathematical Structures with Applications to Computer Science, McGraw-Hill Book Co., 1997.
2. J.L. Gersting, Mathematical Structures for Computer Science, (3rd edition), Computer Science Press, New York.
3. Seymour Lipschutz, Finite Mathematics (International edition 1983). McGraw-Hill Book Company, New York.
4.S. Wiitala, Discrete Mathematics-A Unified Approach, McGraw-Hill Book Co.
5. J. E. Hopcroft and J.D. Ullman, Introduction to Automata Theory, Languages & Computation, Narosa Publishing, House.
6. C.L. Liu, Elements of Discrete Mathematics, McGraw-Hill Book Co.
7. N. Deo, Graph Theory with Applications to Engineering and Computer Sciences, Prentice hall of India.

Course code	**MA-644**	**Course Name**	**Project/Dissertation**
Programme	M.Sc. Mathematics	Credits	6(L-0,T-0,P-12)
Hrs/Week	12	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	-	Pre-requisite of course	NIL
Course Objective	The purpose of this course is to enhance writing and communication skills and how to present subject and ongoing researches.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Will be able to present research work in the field. 2: Get ability to write subject in own way. 3: Skills to know future of the subject. 4: Get knowledge of preparing Dissertation, Thesis and Books.		

NOTE:

1. Internal evaluation of the project/dissertation will be on the regular basis by two periodic presentations before the final submission of project/dissertation. Each presentation will be evaluated in 15 marks.
2. The final project/dissertation submitted by the student will be evaluated by two examiners, one internal examiner which will be Guide/Supervisor/Course Co-ordinator and other will be external examiner decided by the University. The weightage of both examiners will be of 35 marks each. (Total marks - 70)

COURSE SYLLABUS

Units	Content of Each unit
1	Each student will have to submit his/her Project/Dissertation on the topic on which he/she had submitted the proposal/synopsis in 3rd semester under the supervision of Guide/Supervisor/Course Co-ordinator. The plagiarism of the submitted project/presentation must be less than 20%.

MOOC/DCEC Courses offered for M.Sc. (Mathematics) students only

Course code	**MA-645(a)**	**Course Name**	**Theory of Relativity and Cosmology**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The purpose of this course is to understand the concept of theory of relativity and cosmology and its applications in real life.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Will be able to understand the concept of theory of relativity. 2: Get ability to learn about Planetary orbits. 3: Skills to know Cosmological models. 4: Get knowledge of Hubble's law & cosmological principles.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Review of the special theory of relativity and the Newtonian Theory of gravitation, Principles of equivalence and general covariance, geodesic principle, Newtonian approximation of relativistic equations of motion. Einstein's field equations and its Newtonian approximation.
2	Schwarzschild external solution and its isotropic form, Planetary orbits and analogues of Kepler's Laws in general relativity. Advance of perihelion of a planet, Bending of light rays in gravitational field, gravitational red-shift of spectral lines. Radar echo delay.
3	Einstein's modified field equations with cosmological term, Static cosmological models of Einstein and De-Sitter, their derivation, properties and comparison with the actual universe.
4	Hubble's law. Cosmological principles. Weyl's postulate, Derivation of Robertson-Walker metric. Hubble and deceleration parameters. Redshift : Redshift versus distance relation, Angular size versus Redshift relation and source counts in Robertson-Walker space-time. Friedmann models. Closed and open universes. Einstein-de-Sitter model. Particle and event horizons.

Suggested Readings

1. H. Stephani, Genereal Relativity. An Introduction of the theory of the gravitational field. Cambridge University Press, 1982.
2. A. S. Eddington, The Mathematical Theory of Relativity, Cambridge University, Press, 1965.
3. J.V. Narlikar, General Relativity, and Cosmology. The Macmillan Company of India Ltd., 1978.
4. R. Adler, M. Bazin, M. Schiffer, Introduction to General Relativity, McGraw Hill Inc., 1975.
5. B. F. Shutz, A first course in general relativity, Cambridge University Press, 1990.
6. S. R. Roy and Raj Bali, Theory of Relativity, Jaipur Publishing House, Jaipur, 1987.

Course code	**MA-645(b)**	**Course Name**	**Fuzzy Set Theory**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to introduce the		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the occurring of difference equations and linear difference equations. Also will be able to solve these equations 2: Understand the non-linear difference equations and their linearization. 3: Understand the System of difference equations. 4. Understand the nonlinear difference equations and their systems.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Basic definition of fuzzy set, a-level sets, Convex fuzzy sets, Basic operations on fuzzy sets, Types of fuzzy sets, Cartesian products, Algebraic products, Bounded sum and difference, t-norms and t-conorms.
2	The Zadeh's extension principle, Image and Inverse image of fuzzy sets, Fuzzy numbers, Elements of fuzzy arithmetic, Fuzzy relations on fuzzy sets, Composition of fuzzy relations, Fuzzy equivalence relations, Fuzzy relation equations, Fuzzy graphs, Similarity relation.
3	Fuzzy measures, Evidence theory, Necessity measure, Possibility measure, Possibility distribution, Possibility theory on fuzzy sets, Possibility theory versus probability theory, Overview of classical logic, Multivalued logics, Fuzzy propositions, Fuzzy quantifiers.
4	An overview of fuzzy expert system, Fuzzy implications and their selection, Multiconditional approximate reasoning, Role of fuzzy relation equation, Fuzzy controllers, Fuzzy rule base, Fuzzification and Defuzzification, Various defuzzification methods.

Suggested Readings:

1. Hans J. Zimmermann, Fuzzy Set Theory and Its Applications, Springer Publication.
2. A. K. Bhargava, Fuzzy Set Theory, Fuzzy Logic and their Applications, S. Chand & Company, 2013.
3. C. Mohan, An Introduction to Fuzzy Set Theory and Fuzzy Logic, Viva Books Publisher.
4. G. Chan and T. T. pham, Fuzzy sets, Fuzzy logic and Fuzzy Control Systems, CRC Press New York.
5. George, J. Klir and Bo Yuan, Fuzzy Sets and Fuzzy Logic : Theory and Applications, Pearson Publication.

Course code	MA-645(c)	Course Name	Space Dynamics
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	Space dynamics provides an opportunity to understand the motion of centre of mass, the three body problem, motion of motion and rocket performance.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Use the concepts of Kepler's equation. 2: State and explain the Lagrange's planetary equations and osculating orbit. 3: Apply the theorems for studying motion of moon. 4: Describe the analysis of performance of rockets.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Basic formulae of a spherical triangle- The two body problem, the motion of the centre of mass. The relative motion, Kepler's equation, Solution by Hamilton-Jacobi theory. The determination of orbits-Laplace and Gauss Methods.
2	The three Body problem: general three body problem, restricted three body problem, Jacobi Integral, curves of zero velocity, Stationary solutions and their stability. The n-body problem- The motion of the center of mass, Classical integrals. Pertubation - Osculating orbit, perturbing forces. Secular and periodic perturbations. Langrange's Planetory Equations in terms of perturbing forces and in terms of a perturbed Hamiltonian.
3	Motion of the moon-the perturbing forces, perturbations of Keplerian elements of the Moon by the Sun. Flight mechanics- Rocket performance in a vacuum. Vertically ascending paths. Gravity twin trajectories. Multi stage rocket in vacuum. Definitions pertinent to single stage rockets.
4	Performance limitations of single stage rockets, definitions pertinent to multi stage rockets, Analysis of multistage rockets including gravity. Analysis of multistage rockets neglecting gravity. Rocket performance with Aerodynamic forces. Short range non-lifting missiles, Ascent of a sounding rocket. Some approximate performance of rocket- powered air-craft.

Suggested Readings:
1. J.M.A. Danby, fundamentals of Celestial Mechanics, The Macmillan Company.1962.
2. E.Finlay, Freundlich ,Celestial Mechanics, The Macmillan Company,1958.
3. Theodore E.Sterne, An Introduction of Celestial Mechanics, Intersciences Publishers, Inc.1960.
4. Arigelo Miele, Flight Mehanics-Vol1, Theory of flight paths, Addison-wesley publishing company, Inc.,1962

Course code	**MA-645(d)**	**Course Name**	**Advanced Fluid Dynamics**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to provide a treatment of topics in magneto hydrodynamics, boundary layer theory and an appreciation of their application to real world problems.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the boundary layer theory. 2: Define Karman's Integral Equations and its properties. 3: Understand the magneto-hydrodynamics and wave propagation. 4: Understand the shock wave and its properties.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Prandtls' boundary layer theory and its importance, Boundary layer Thickness. Displacement Thickness, Momentum thickness, Energy Thickness, Drag and lift. The boundary layer equation in two dimensional flow. The boundary layer flow over a flat plate. Determination of shearing stress and boundary layer thickness.
2	Karman's integral equation, Application of the boundary layer in absence of pressure gradient. Application of the Karman's integral equation to boundary layer with pressure gradient : Karman-Pohlhausen method.
3	Basic equations of inviscid and viscous magnetohydrodynamics. The Alfven wave. Effect of finite conductivity on hydrodynamic waves. The equation of incompressible magneto-hydrodynamic flow, Parallel steady flow. One dimensional steady viscous flow. Hartman flow, Magnetohydrodynamic characteristic equations.
4	Properties of fast, slow, transverse and entropy waves. One dimensional wave propagation Contact surfaces and transverse simple waves. Fast and slow simple waves. Magnetohydroynamic shock waves. Shock waves in non-conducting gas with finite viscosity and Thermal conductivity MHD effect in stock formation.

Suggested Readings:

1. Allen Jeffery – Magnetohydrodynamics (Oliver & Boyd)
2. P. C. Kendell and C. Plumton – Magnetohydrodynamics with hydrodynamics – Vol 1 (Pergamon Press).
3. F. Chorlton – A Text Book of Fluid Dynamics.
4. M. D. Raisinghania & R.S. Agarwal – Advanced Hydrodynamics & Fluid Dynamics.

Course code	**MA-645(e)**	**Course Name**	**Introduction to Cryptography**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The purpose of the course is to give a simple account of cryptography. Upon completion of the course, students will have a working knowledge of the fundamental definitions and theorems of elementary congruences, solve congruence equations and systems of equations with one and more variables. They will understand the language, notation of Caesar Cipher and explored to cryptography. We will also discussion on Diffie-Hellman RSA public key cryptosystem.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the operations with congruence's, linear and non-linear congruence equations. 2: Use the basics of RSA security and be able to break the simplest instances and analyse the basic concepts of remote coin flipping, elliptic curve based cryptography. 3: Understand and use the numbers: Perfect numbers, Fermat numbers, Mersenne primes and amicable numbers, Fibonacci numbers. 4: Apply the theorems: Fermat's last theorem, prime number theorem and zeta function.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Modular arithmetic, congruence, primitive roots, cryptography introduction, Caesar Cipher, Diffie-Hellman RSA public key cryptosystem, Knapsack cryptosystem, application of primitive roots to cryptography
2	Applications of cryptography in primality testing and factorization of large composite numbers, remote coin flipping. Elliptic curve based cryptography.
3	Perfect numbers, Fermat numbers, Mersenne primes and amicable numbers, Fibonacci numbers, representation of integers as sum of Squares.
4	Linear and non-linear Diophantine equations, Fermat's last theorem, prime number theorem and zeta function.

Suggested Readings:

1. Tilborg, H. C. A. Fundamentals of Cryptology. Springer, 2013.
2. Buchmann, J. A. Introduction to Cryptology.Springer Science & Business Media, 2012
3. Burton , D. M. Elementary Number Theory, Tata McGraw Hill Publishing House, 2006.
4. Menezes, A. J., V.,Oorschot, P. C. and Vanstone,S. A. Handbook of Applied Cryptography. CRC Press, 1996.
5. Koblitz, N. A Course in Number Theory and Cryptography. 2 nd edition Springer, 1994. 6. Simmons, G. J. Contemporary Cryptology, The Science of Information Integrity.New York, IEEE Press, 1992.

Course code	**MA-645(f)**	**Course Name**	**Mechanics**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The course objective is to familiarize the students with problem solving through generalized co-ordinates, Hamilton's variables and understanding of Brachistochrone problem.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: General concept of mechanics and overview Lagrange's equations of I and II kind. 2: Acquire knowledge of Hamilton canonical equations. 3: Learn about Isoperimetric problems and fundamental lemma of CoV. 4: Study Hamilton-Jacobi equation and the concept of brackets.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Generalized co-ordinates. Holonomic and Non- holonomic systems, Scleronomic and Rheonomic systems. Generalized potential. Lagrange's equations of first kind. Lagrange's equations of second kind. Uniqueness of solution. Energy equation for conservation fields.
2	Hamilton's variables, Donkin's Theorem. Hamilton canonical equations. Cyclic co-ordinates. Routh's equations. Poisson's brackets. Poisson's identity, Jacobi-Poisson Theorem. Motivating problems of Calculus of variations, shortest distance, Minimum surface of revolution.
3	Brachistochrone problem. Isoperimetric problem. Geodesic, fundamental lemma of calculus of variations. Euler's equation for one dependent function and its generalization to (i) 'n' dependent functions, (ii) higher order derivatives. Conditional extremum under geometric constraints and under integral constraints. Hamilton's Principle : Principle of least action. Poincare Carton Integral invariant. Whittaker's equations, Jacobi equations. Statement of Lee Hwa Chung's Theorem.
4	Hamilton-Jacobi equation. Jacobi Theorem. Method of separation of variables. Lagrange Brackets. Condition of canonical character of a transformation in terms of Lagrange brackets and Poisson brackets. Invariance of Lagrange Brackets and Poisson brackets under canonical transformations.

Suggested Readings:

1. A. S. Ramsey, Dynamics Part II, The English Language Book Society and Cambridge University Press, 1972.
2. F. Gantmacher, Lecturers in Analytic Mechanics, MIR Publishers, Moscow, 1975.
3. H. Goldstein, Classical Mechanics (2^{nd} edition), Narosa Publishing House, New Delhi.
4. Narayan Chandra Rana and Pramod Sharad Chandra Joag, Classical Mechanics, Tata McGraw Hill, 1991.
5. Louis, N. Hand, Janet D. Finch, Analytical Mechanics, Cambridge University Press, 1998.
6. I. M. Gelfand and S. V. Fomin, Calculus of variations, Prentice Hall.
. Springer-Verlag, 2005.

Course code	**MA-645(g)**	**Course Name**	**Wavelet Analysis**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The course objective is to familiarize the students with Fourier series, Fourier transform, Gabor Transform and Wavelet analysis.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Overview Fourier series. 2: Acquire knowledge of Fourier transform. 3: Learn about Wavelet transform. 4: Acquire knowledge of mother wavelet.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Motivation and Definition of Fourier Series, Fourier Series over the interval of length 2π, complex form of a Fourier series, Convergence of Fourier Series, Riemann Lebesgue Lemma, Convergence at a point and uniform convergence.
2	Motivation and Definition, Basic properties, Fourier Transforms in $L^1(\mathbf{R})$ and $L^2(\mathbf{R})$, Poisson summation formula, Sampling theorem, Heisenberg's uncertainty principle, Discrete Fourier Transform, Fast Fourier Transform.
3	Motivation and Definition, Gabor transform, Continuous wavelet transform, Basic properties of Wavelet Transform, Discrete Wavelet Transform.
4	Definition and examples, Construction of Mother Wavelet, Orthonormal spline wavelets, Construction of compactly supported Wavelets, Mallat's algorithm.

Suggested Readings:

1. K. Ahmad and F.A. Shah: Introduction to wavelets with Applications, Real World Education Publishers, New Delhi (2013).
2. G. Bachmann, L. Narici and E. Beckenstein: Fourier and Wavelet Analysis, Springer-Verlag (1999).
3. C.K. Chui: An Introduction to Wavelets, Academic Press, New York (1992).
4. I. Daubeschies: Ten Lectures on Wavelets, SIAM, Philadelphia, PA, USA (1992).

MOOC/GEC Courses offered to PG students of other than PG Mathematics students

Course code	**MA-646(a)**	**Course Name**	**Graph Theory**
Programme	M.Sc. Mathematics	Credits	4(L-3,T-1,P-2)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of the course is to introduce students with the fundamental concepts in graph theory, with a sense of some its modern applications. They will be able to use these methods in subsequent courses in the design and analysis of algorithms, computability theory, software engineering, and computer systems.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the graphs. 2: Familiarize with Knowledge based trees and cut-sets. 3: Apply the aspect of matrix representation of graphs. 4: Recognize the concepts of directed and undirected graphs.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Definition of (undirected) Graphs Paths, Circuits; Cycles, and Subgraphs. Induced Subgraphs. Degree of a vertex. Connectivity. Planar Graphs and their properties.
2	Trees, Euler's Formula for connected Planar Graphs. Complete and Complete Bipartite Graphs. Kuratowski's Theorem (statement only) and its use. Spanning Trees, Cut-sets, Fundamental Cut-sets, and Cycles.
3	Minimal Spanning Trees and Kruskal's Algorithm. Matrix Representations of Graphs, Euler's Theorem on the Existence of Eulerian Paths and Circuits. Directed Graphs.
4	In degree and Out degree of a vertex. Weighted undirected Graphs. Dijkstra's Algorithm. Strong Connectivity and Warshall's Algorithm. Directed Trees. Search Trees. Tree Traversals.

Suggested Readings:

1. J.P. Tremblay & R. Manohar, Discrete Mathematical Structures with Applications to Computer Science, McGraw-Hill Book Co., 1997.
2. J.L. Gersting, Mathematical Structures for Computer Science, (3rd edition), Computer Science Press, New York.
3. Seymour Lipschutz, Finite Mathematics (International edition 1983). McGraw-Hill Book Company, New York.
4. S. Wiitala, Discrete Mathematics-A Unified Approach, McGraw-Hill Book Co.
5. J.E. Hopcroft and J.D. Ullman, Introduction to Automata Theory, Languages & Computation, Narosa Publishing, House.
6. C.L. Liu, Elements of Discrete Mathematics, McGraw-Hill Book Co.

Course code	**MA-646(b)**	**Course Name**	**Mathematics for Chemists**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The main objective of this course is to introduce the students to the exciting world of Mathematics in medical science and its applications.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Learn the basics of limit, continuity and differentiability. 2: Understand the methods for finding the solution of differential equations. 3: Familiarize with matrices and elementary operations on matrices. 4: Use the basics tools of statistics to test the null and alternative hypothesis.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Limit, continuity and differentiability of function of single variable, Successive Differentiation, Expansion of simple functions, Partial Differentiation and Jacobian, Indeterminate forms.
2	Solution of differential equations, first-order linear equations- separable equations, homogeneous linear equations, non-homogeneous linear equations, second-order differential equations with constant coefficients, general solution, particular solution, linear equations in chemical kinetics, harmonic oscillator and some other applications.
3	Types of Matrices, Elementary operations on Matrices, Rank of a Matrix, Echelon form of a Matrix, Normal form of a Matrix, Inverse of a Matrix by elementary operations, System of linear homogeneous and non-homogeneous equations, Theorems on consistency of a system of linear equations.
4	Theory of sampling and its objective, Types of population, Null hypothesis and Alternative hypothesis, Data collection, Level of significance, Procedure for testing a hypothesis.

Suggested Readings:

1. J.K. Goyal & J.N. Sharma, Mathematical Statistics.
2. M.Ray& H.S. Sharma, Mathematical Statistics, Ram Prasad &Sons.
3. G. Strang, Calculus, MIT, Cambridge Press.
4. S. Narayan and P. K. Mittal, A text book of Matrices, S. Chand Publication.

Course code	**MA-646(c)**	**Course Name**	**Mathematical Modeling**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objectives of this course are to: • Enable students understand how mathematical models are formulated, solved and interpreted. • Make students appreciate the power and limitations of mathematics in solving practical real-life problems. • Equip students with the basic mathematical modelling skills.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand what a mathematical model is and explain the series of steps involved in a mathematical modelling process. 2: Use applications of mathematical modelling through difference equations. 3: Understand and apply the concept of mathematical modelling through difference equations in population dynamics, genetics and probability theory. 4: Apply the concept of mathematical modelling through graph theory.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Simple situations requiring mathematical modelling, techniques of mathematical modelling, classifications, characteristics and limitations of mathematical models, some simple illustrations, mathematical modelling in population dynamics, mathematical modelling of epidemics through systems of ordinary differential equations of first order mathematical models in medicine, battles and international trade in terms of systems of ordinary differential equations.
2	The need for mathematical modelling through difference equations, linear growth and decay models, non-linear growth and decay models, basic theory of linear difference equations with constant coefficients, mathematical modelling through difference equations in economics and finance.
3	Mathematical modelling through difference equations in population dynamics and genetics, mathematical modelling through difference equations in probability theory, miscellaneous examples of mathematical modelling through difference equations.
4	Situations that can be modelled through graphs, mathematical models in terms of directed graphs mathematical models in terms of signed graphs, mathematical models in terms of weighted graphs.

Suggested Readings:

1. Kapur J. N. Mathematical Modelling, 2nd edition, New Age International, 2015.
2. Meerschaert, M. M. Mathematical Modelling. Academic Press, 2013.
3. Rutherford, A. Mathematical Modelling Techniques. Courier Corporation, 2012.
4. Clive,L. D. Principles of Mathematical Modelling. Elsevier, 2004.
5. Bender, E. A. An Introduction to Mathematical Modelling. Courier Corporation, 2000.

Course code	MA-646(d)	Course Name	Bio-Statistics
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to introduce basic and advanced topics in information theory. This course further explains the different types of entropies, codes, discrete and continuous channels and their applications.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the basic concepts of information theory, different types of entropies with their properties and applications. 2: Analyse how different coding techniques will perform in different situations. 3: Understand about discrete channels and their properties with applications. 4: Understand about continuous channels and their properties with applications.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Probability: Classical Probability, Axiomatic Approach, Conditional Probability, Independent Events, Addition and Multiplication Theorems with applications, Bayes' theorem. Random variables : Probability mass function, probability Density function.
2	Expectation, Variance, Standard Deviation, Some Distributions and Their Applications : Uniform, Bernoulli, Binomial, Poisson and Normal. Joint Distribution : Joint and Marginal Distributions, Covariance, Correlation, Independent random variables.
3	Sequences of Random Variables : Central Limit Theorem. Sampling : Sampling Distribution, Sample Mean and Variance, Standard Error, Sample Correlation, Standard Normal Distribution, t-distribution, Chi-square distribution, Point Estimation, Confidence Intervals, ANOVA table.
4	Hypothesis Testing : Null and Alternate Hypothesis, Type I and Type II Errors, Large Sample Tests, Small Sample Tests, Power of a Test, Goodness of Fit, Chi-Square Test, Linear Regression.

Suggested Readings:

1. J. Medhi; Statistical Methods, New age International (P) Ltd.
2. A. J. Medhi Festschrift: Prob. &Models and Statistics, New Age International (P) Ltd.
3. Hogg (Reprint ISBN-8178086301): Introduction of Mathematical Statistics, Pearson Education.
4. J.K. Ghosh, Mathematical Statistics, John Wiley & Sons, New York.
5. J.K. Goyal & J.N. Sharma, Mathematical Statistics.
6. M. Ray & H.S. Sharma, Mathematical Statistics, Ram Prasad &Sons.
7. Gupta and Kapoor, Mathematical Statistics , S.Chand, New Delhi.
8. Goon, Gupta, Dasgupta, Fundamental of Mathematical Statistics and Applied Statistics.

Course code	**MA-646(e)**	**Course Name**	**Research Methodology**
Programme	M.Sc. Mathematics	Credits	5(L-4,T-2,P-0)
Hrs/Week	6	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.- 70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	Research methodologies tell the systematic methods for acquiring data and studying it for deriving out crucial findings. This is an important process that helps in solving problems and making decisions.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the basic concepts of research methods and different types of research. 2: Formulation of research problem and its necessity. 3: Understand about Research design and Experimental design. 4: Understand about research ethics and plagiarism.		
NOTE: Eight questions will be set, two from each of the UNIT. The candidates are required to attempt any five questions in all selecting atleast one question from each section. All Questions carry equal marks.			

COURSE SYLLABUS

Units	Content of Each unit
1	Motivation and objectives – Research methods vs. Methodology. Types of research – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical, concept of applied and basic research process, criteria of good research.
2	Defining and formulating the research problem, selecting the problem, necessity of defining the problem, importance of literature review in defining a problem, literature review-primary and secondary sources, reviews, monograph, patents, research databases, web as a source, searching the web, critical literature review, identifying gap areas from literature and research database, development of working hypothesis.
3	Research Design: Concept and Importance in Research – Features of a good research design – Exploratory Research Design – concept, types and uses, Descriptive Research Designs – concept, types and uses. Experimental Design: Concept of Independent & Dependent variables.
4	Ethics-ethical issues, Patent law, commercialization, copy right, royalty, trade related aspects of intellectual property rights (TRIPS); scholarly publishing, design of research paper, citation and acknowledgement, plagiarism, reproducibility and accountability.

Suggested Readings:

1. C.R.Kothari : Research Methodology: Methods and Techniques, New Age International Publishers.
2. S.B.Mishra, Shashi Alok : Handbook of Research Methodology, Educreation Publishers.
3. N. K. Denzin, Y. S. Lincon : Handbook of Qualitative Research, SAGE Publishing.
4. M. Depaepe, P. Smeyers : The SAGE handbook of Qualitative Research, SAGE Publishing.