DEPARTMENT OF MATHEMATICS AND STATISTICS
DDU GORAKHPUR UNIVERSITY
GORAKHPUR-273009 (U.P.)
INDIA

National Education Policy-2020

Choice Based Credit System (CBCS)

Syllabus

for

M.A. /M.Sc. Program

in

MATHEMATICS

(Effective from Academic Session 2022-2023)

Title of the Program: M.A./M.Sc. (Mathematics)

based on

National Education Policy-2020

in

Choice Based Credit System (CBCS)

The proposed curriculum is expected to provide the students a good overall knowledge of Mathematics covering various aspects. They will not only be able to understand the important mathematical techniques but also able to apply some commonly used mathematical techniques to other fields.

Semester Courses of M.A/M.Sc. Mathematics Based on CBCS

The course of M.A/M.Sc. (Mathematics) will be spread in two years - Previous and Final. Each of which will have two semester examinations and therefore will be four semester examinations.

Subject Prerequisites

To study this subject a student must had the subject(s) Mathematics in class B.A. /B.Sc.

Eligibility for Admission

For M. A. / M.Sc. in Mathematics following candidates are eligible.

Candidate shall be eligible for admission if he/she possess Bachelor's Degree under 3 years pattern of education with **Mathematics** as a Major Course in the third year of graduation.

Programme Specific Outcomes (PSOs)

PS01. To develop deep understanding of the fundamental axioms in mathematics and capability of developing ideas based on them.

PS02. To provide advanced knowledge of topics in pure mathematics particularly in Analysis and Geometry empowering the students to proceed with the area at higher level.

PS03. To develop understanding of applied mathematics and motivating the students to usemathematical techniques as a tool in the study of other scientific domains.

PS04. To encourage students for research studies in Mathematics and related fields.

PS05. To provide students a wide variety of employment options as they can adopt research as a career or take up teaching jobs or can get employment in banking or can go for anyother profession.

PS06. To inculcate problem solving skills, thinking and creativity through presentations, assignments and project work.

PS07. To help students in their preparation (personal counselling, books) for competitive exams e.g. CSIR-NET, GATE, etc.

PS08.To enable the students being life-long learners who are able to independently expandtheir mathematical expertise when needed.

Program Duration

The duration of the M.A. /M.Sc. Mathematics program for the candidates admitted in semester I will be of two academic years (4 semesters). The duration of each semester will generally be 90 working days. There are two regular semesters in an academic year.

Examination and Assessment

As prescribed by the University (as per common ordinance for examination and assessment).

Program Structure

M.A./M.Sc. Mathematics program is of minimum 100 credits spread over four semesters in Choice Based Credit System (CBCS). Overall total 25 courses are well spread over 4 semesters. These courses are divided in to four categories- Core Courses/Major Courses (**4 credit each**), Discipline Specific Elective (DSE) Courses/Elective Courses (**4 credit each**), Minor Elective (ME) Course (**4 credit each**) and Project Work (**4 Credit each**).

NUMBER OF COURSES AND CREDITS

S. No.	Types of course	Credit per course	Total Number of course Type	Total credit for the particular type
1	Core	4+0	16	64
2	Discipline Specific Elective	4+0	4	16
3	Minor Elective	4+0	1	4
4	Project	0+4	4	16
Total				100

SEMESTER WISE BREAK-UP OF COURSES

S. No	Types of course	Semester I	Semester II	Semester III	Semester IV	Total
1	Core	5(20)	5(20)	3(12)	3(12)	64
2	Discipline Specific Elective	-----	------	2(8)	2(8)	16
3	Minor Elective	----	1(4)	----	-----	4
4	Project	1(4)	1(4)	1(4)	1(4)	16
Total		5+1 (24)	5+1+1(28)	3+2+1(24)	3+2+1(24)	25 (100)
		52		48		

M.A./M.Sc. Previous (Mathematics)

The M.A./ M.Sc. Previous (Mathematics) examination will consist of two semesters, calledas first and second semesters. In each of these semesters, there will be five compulsory/core/major papers of 4 credits each and one minor elective paper of 4 credits in second semester and in each of these semesters, there will be project of 4 credits and the marks of project based on internal evaluation. Also, there will be internal evaluation in each paper based on attendance/assignment/ project.

FIRST SEMESTER

Paper	Course Code	Course Title	Credits
Core/Major Papers			
Paper I	MAT-501	Groups and Canonical Forms	4+0
Paper II	MAT-502	Topology	4+0
Paper III	MAT-503	Differential and Integral Equations	4+0
Paper IV	MAT-504	Complex Analysis	4+0
Paper V	MAT-505	Real Analysis	4+0
Project			
Paper VI	MAT-506	Research Project (Project based on books of Ancient Indian Mathematicians)	0+4
Total Credits			24

SECOND SEMESTER

Paper	Course Code	Course Title	Credits
Core/Major Papers			
Paper I	MAT-507	Fields and Modules	4+0
Paper II	MAT-508	Differential Geometry of Manifolds	4+0
Paper III	MAT-509	Partial Differential Equations	4+0
Paper IV	MAT-510	Operations Research	4+0
Paper V	MAT-511	Fluid Dynamics	4+0
Project			
Paper VI	MAT-512	Project (Project on Programming in R /Python/ Mathemtica /MATLAB)	0+4
Total Credits			24
# Minor Elective Paper	MAT-513	Basic Statistical Tools for Mathematical Sciences	4+0
Total Credits (I +II Semesters) + (4 credits of minor elective paper in semester II)			52

M.A/M.Sc. Final (Mathematics)

The M.A./M.Sc. Final (Mathematics) will consist of two semesters, called as third and fourth semesters. In each of these semester examinations there will be three compulsory/core/major papers of 4 credits and two elective papers to be selected from each group of optional papers of 4 credits. In third semester, there will be project of 4 credits and in fourth semester, there will be dissertation/survey of 4 credits and the marks of project and dissertation/survey based on internal evaluation. Also, there will be internal evaluation in each paper based on attendance/assignment/ project.

THIRD SEMESTER

Paper	Course Code	Course Title	Credits
Core/Major Papers			
Paper I	MAT-514	Number Theory	4+0
Paper II	MAT-515	Functional Analysis-I	4+0
Paper III	MAT-516	Mathematical Modelling	4+0
Discipline Specific Elective (DSE)/Elective Papers (Any one of the following/Opt any one)			
Paper IV	MAT-517	Advanced Topology	4+0
	MAT-518	General Relativity and Gravitation	4+0
	MAT-519	Summability Theory and Approximation	4+0
	MAT-520	Hydro Dynamics	4+0
	MAT-521	Numerical Solution of Differential Equations	4+0
Discipline Specific Elective (DSE)/Elective Papers (Any one of the following/Opt any one)			
Paper V	MAT-522	Discrete Mathematics	4+0
	MAT-523	Mathematical Epidemiology	4+0
	MAT-524	Complex Manifolds	4+0
	MAT-525	Riemannian Geometry	4+0
	MAT-526	Hydro Statics	4+0
Project			
Paper VI	MAT-527	Project (Project on LaTex & Advance Programming in R/ python/ Mathematica/ MATLAB)	0+4
Total Credits			24

FOURTH SEMESTER

Paper	Course Code	Course Title	Credits
Core/Major Papers			
Paper I	MAT-528	Measure Theory	4+0
Paper II	MAT-529	Functional Analysis-II	4+0
Paper III	MAT-530	Classical Mechanics	4+0
Discipline Specific Elective (DSE)/Elective Papers (Any one of the following/Opt any one)			
Paper IV	MAT-531	Fourier Analysis	4+0
	MAT-532	Cosmology	4+0
	MAT-533	Wavelet Analysis	4+0
	MAT-534	Magneto Hydrodynamics	4+0
	MAT-535	Mathematics for Humanities (Not for Mathematics Students)	4+0
Discipline Specific Elective (DSE)/Elective Papers (Any one of the following/Opt any one)			
Paper V	MAT-536	Fixed Point Theory and its Application	4+0
	MAT-537	Bio Mathematics	4+0
	MAT-538	Contact Manifolds	4+0
	MAT-539	Finsler Geometry	4+0
	MAT-540	Mathematics for Life Sciences (Not for Mathematics Students)	4+0
Dissertation/Survey			
Paper VI	MAT-541	Dissertation/Survey (Based on any one core or discipline specific elective/elective papers opted by the student in Semester-I or II or III or IV)	0+4
Total Credits			24
Total Credits (III +IV Semesters)			48
Total Credits (I+II+III +IV Semesters)			100

M.A/M.Sc. First Semester (Mathematics)

Paper	Course Code	Course Title	Total Credit
I	MAT-501	Groups and Canonical Form	4+0

Course Objectives: The paper of Group & Canonical form is introduced to M.Sc. classes for the study of structure of groups and properties of matrices. The main objective of group theory is that to prepare the students for further research in modern algebra.

Unit I

Groups**:** Conjugacy relation. Normalizer of an element, Class equation of a finite group, Center of a group, Fundamental theorems on isomorphism of groups, Automorphisms, Inner automorphism.

Unit II

Maximal subgroups, Commutator subgroups, Composition series, Examples of Composition series and normal series. Jordan-Holder theorem, Solvable groups, Solvable subgroups, Nilpotent groups.

Unit III

External and internal direct product of groups, Cauchy's theorem for finite group, Cauchy's theorem for abelian group, Groups of order p^2 and pq, Sylow's p subgroups, Sylow's first, second and third theorems. Application of Sylow's theorems to find the number of Sylow's p subgroups of a finite groups.

Unit IV

Canonical forms: Similarity of linear transformations, Invariant subspaces, Reduction to triangular forms, Nilpotent transformations, Index of nilpotency, Invariants of a nilpotent transformation, The primary decomposition theorem, Jordan blocks and Jordan forms.

Books Recommended:

1. I.N. Herstein: Topics in Algebra, Wiley Eastern Ltd., New Delhi.
2. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul Basic Abstract Algebra (Second Edition), Cambridge University Press, Indian Edition.
3. Surjeet Singh and Qazi Zameeruddin: Modern Algebra, Vikas Publishing House. Pvt. Ltd.
4. K.B. Datta:Matrix and Linear Algebra, Prentice Hall of India Pvt. Ltd., New Delhi,.
5. S. Kumaresan: Linear Algebra, A Geometric Approach, Prentice Hall of India.
6. A.R. Vasishtha & A.K. Vasishtha: Modern Algebra, Krishna Prakashan Media (P) Ltd., Meerut.
7. H.K.Pathak: Abstract Algebra, Shiksha Sahitya Prakashan.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. understand Group theory covering a wide area of research in abstract algebra.

CO 2. understand Sylow's theorems, group homomorphism, isomorphism etc are used to define the structureof groups as well as it is applicable in physical and chemical sciences.

CO 3. gainconceptual understanding of the course for qualifying various competitive exams such as CSIR-NET (JRF), IAS,PCS and other teaching jobs.

Paper	Course Code	Course Title	Total Credit
II	**MAT-502**	**Topology**	**4+0**

Course Objectives: (i) To give ideas and method which transformed large parts of geometry and analysis almost beyond recognition.
(ii) To stimulate the growth of abstract Algebra.
(iii) Topology is concern with the properties of a geometric object that are preserved under continuous deformations such asstretching, twisting crumpling and bending but not tearing and gluing.

Unit 1

Definition and examples of topological spaces. Closed sets. Closure. Dense subsets. Neighbourhoods. Interior, exterior and boundary. Accumulation points and derived sets. Bases and sub-bases. Subspaces and relative topology. Neighbourhood Systems.

Unit II

Continuous functions and homeomorphism, The Pasting lemma. First and second countable spaces. Lindelof's theorems. Separable spaces. Second Countability and Separability.

Unit III

Separation axioms T_0,T_1,T_2,T_3,T_4; their characterizations and basic properties. Urysohn Lemma. Tietze extention theorem.

Unit IV

Compact sets and their properties. Finite intersection property, Bolzano Weierstrass property. Continuous functions and compactness, Sequential compactness, countable compactness and their comparison. One point compactification. Connected spaces. Connectedness on the real line. Components. Locally connected Spaces.

Books Recommended:

1. George F. Simmons : Introduction to Topology and Modern Analysis, Mc Graw-Hill Book Company.
2. J.L. Kelley : General Topology, Van Nostrand, Reinhold Co., New York.
3. K.D. Joshi: Introduction to General Topology, Wiley Eastern Ltd.
4. James R Munkres : Topology, Prentice Hall of India Pvt. Ltd., New Delhi.
5. Willard: General Topology Addison-Wesley, Reading.

Course Outcomes: After the completion of the course
CO 1. They are able to understand the concept of theory of continuous curve, differentiable and Riemannian manifold and lie groups with their applications.
CO 2. They can easily understand the theory of Banach and Hilbert spaces and their operators.
CO 3. They are able to understand abstract Harmonic analysis on locally compact groups.

Paper	Course Code	Course Title	Total Credit
III	MAT-503	Differential and Integral Equations	4+0

Course Objectives: The objective of this course is to study differential equations of second order with variable coefficients, series solution and the emergence of some special functions and their properties. The additional objective of this course is to introduce Fredholm and Volterra type of integral equations. This course also relates differential equations with integral equations.

Unit I

Series solution of differential equations of second order with variable coefficients and emergence of special functions, orthogonal sets of function, orthogonality of some special functions, Hermite orthogonality of a set of complex valued functions, Sturm-Liouville equation, Sturm-Liouville problem, Hypergeometric differential equation, Papperitz symbol, Pochhammer symbol, Hypergeometric function, Solution of Gauss's Hypergeometric Differential Equation, differentiation of Hypergeometric functions, Hermite's differential equation and its solution, Hermite's polynomials, generating function for $H_n(x)$, Rodrigue's formula for $H_n(x)$, orthogonality of Hermite's polynomials, recurrence formulae for Hermite's polynomials.

Unit II

Legendre's differential equation and its solution, Legendre's functions, Rodrigue's formula for$P_n(x)$, generating function for $P_n(x)$, Laplace definite integrals for $P_n(x)$, orthogonality of Legendre's polynomials, recurrence formulae for Legendre's polynomials, Beltrami result. Bessel's differential equation and its solution, Bessel's functions, generating function for $J_n(x)$, differential equations reducible to Bessel's differential Equations, orthogonality of Bessel's functions, recurrence formulae for Bessel's polynomials.

Unit III

Introduction of integral equations, linear integral equations, types of linear integral equations, types of Kernels, conversion of differential equations to integral equations, L_2 kernels and L_2functions, eigen values and eigen functions, solution of Volterra integral equations by successive approximations and successive substitution methods.

Unit IV

Fredholm integral equations of first and second kinds, solution of Fredholm integral equations by Successive approximations and successive substitution methods, Neumann Series, Volterra solution of Fredholm integral equation of second kind, reduction of Volterra integral equation into differential equation.

Books Recommended:

1. V. S.Verma, Series Solution and Special Functions, Neel Kamal Prakashan, Gorakhpur, 2017.
2. V. S.Verma, Fundamentals of Integral Equations Neel Kamal Prakashan, Gorakhpur, 2018.
3. M D Raisinghania, Mathematical methods, Kedarnath, Ramnath, Meerut, 1996.
4. JN Sharma, RK Gupta, Special functions, Krishna Prakashan Media (P) Ltd, 2020.

Course Outcomes: After the completion of the course, the students shall be able to

CO 1. learn the series solution of differential equation of second order with variable coefficients

CO 2. formulate and solve initial and boundary value problems.

CO3. solve linear Volterra and Fredholm integral equations using appropriate methods and understand the relationship between integral and differential equations.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-504**	**Complex Analysis**	**4+0**

Course Objectives: The paper of Complex Analysis is introduced to M.Sc. classes for the study of power series and its region of convergence, analytic continuation, conformal mapping, Schwarz's lemma and related results for further study. The main objective of complex analysis is that to prepare the students for further research in analysis and complex analysis.

Unit I

Conformal Mapping, Mobius (Bilinear) transformations: involving circles and half-planes, fixed point, cross ratio, Transformations $w=z^2$, $w = \tan^2 (z/2)$.

Unit II

Power series and its convergence. Analyticity of power series, singularity of power series, Gamma function. Zeta Function

Unit III

Analytic continuation. Uniqueness of analytic continuation. Power series method of analytic continuation. Natural boundary.

Unit IV

Maximum-modulus theorem. Schwarz's lemma. Hadamard's three-circles theorem. Borel-Cartheodory theorem. Pharagmen- Lindelof theorem.

Books Recommended:

1. E.C. Titchmarsh: Theory of Functions, Oxford University Press, London.
2. Mark J. Ablowitz and A.S. Fokas: Complex Variables: Introduction and Applications, Cambridge University Press, South Asian Edition, 1998.
3. R.V. Churchill & J.W. Brown. Complex Variables and Applications, 5th Edition McGraw-Hill, New York, 1990.
4. Shanti Narayan: Theory of Functions of a Complex Variable, S. Chand & Co., New Delhi.
5. S. Ponnusamy, Foundation of Complex Analysis, Narosa Publication.

Course Outcomes: After the completion of the course, the students shall be able to

CO 1. understand the use of this course in different field of mathematical Analysis.

CO 2. think and develop new ideas in complex analysis.

CO 3. get benefit of this course in various national and international competitive examinations.

Paper	Course Code	Course Title	Total Credit
V	MAT-505	Real Analysis	4+0

Course Objectives: The paper of Real Analysis is introduced to develop in a rigorous and self-contained manner the elements of real variable functions. The main objective of real analysis is that to prepare the students for further research in analysis and differential geometry.

Unit I

Functions of Bounded Variation and some properties of function of bounded variation, Lipschitz condition and function. Variation function, Positive Variation function, Negative Variation function and The Jordan Decomposition theorem.

Unit II

Definition and Existence of Riemann- Stieltjes integrals. Properties of the integral, integration and differentiation, the first and second mean value theorem, the fundamental theorem of integral calculus, change of variable and Integration by parts for Riemann- Stieltjes. Relation between Riemann and Riemann- Stieltjes integral. Riemann- Stieltjes integrals and bounded variation.

Unit III

Sequences of functions of real numbers and its related examples. Pointwise convergence and uniform convergence. CauchyCriterion of uniform convergence, M_n test, Weierstrass M- test, everywhere continuous but nowhere differentiable functions. Dini's Criterion of uniform convergence. Uniform convergence and continuity. Continuity of limit function. Uniform convergence and Riemann Stieltjes integration, Uniform convergence and differentiation.

Unit IV

Abel's and Dirichlet's tests for uniform convergence. Connections between Riemann- Stieltjes integrals, uniform convergence and bounded variation. Curves, Rectifiable curves, Additive and Continuity properties of arc length. Power series, Radius of convergence and interval of convergence, Formulas for determining the radius of convergence, Uniqueness theorem for power series, First and Second form of Abel's theorem and Tauber's theorem for power series.

Books Recommended:

1. Walter Rudin: Principles of Mathematical Analysis (3rd edition), McGraw-Hill, Kogakusha, 1976 International Student Edition.

2. H. L. Royden: Real Analysis, Macmillan Pub. Co. Inc. New York, 4th Edition, 1993.

3. Richard Johnson Baugh: Foundation of Mathematical Analysis.

4. H. K. Pathak: Real Analysis, Shiksha Sahitya Prakashan.

5. Apostol: Mathematical Analysis, Narosa Publishing House.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. demonstrate ability to think critically by proving mathematical conjectures and establishing theorems.

CO 2. demonstrate an intuitive and computational understanding of bounded variation, Uniform convergence and power series through solving application problem.

CO 3. enter into wide area of research in analysis and differential geometry. Also get benefit of this course in various national and international competitive examinations.

Paper	Course Code	Course Title	Total Credit
VI	**MAT-506**	**Research Project/ Project** (the marks of project based on internal evaluation)	**0+4**

Course Objectives: The objective of course is to know introduction and contribution of Ancient Indian Mathematicians in mathematics.

Candidate/Students should write a project based on any one of the following books with brief introduction of author and its contribution in mathematical sciences.

(i) Aryabhattiyam by Aryabhat
(ii) Bijganittam by Bhaskaracharya-II
(iii) Lilavati by Bhaskaracharya-II
(iv) Patiganita by Sridharacharya
(v) Brihat Jataka by Varahamihira
(vi) Brahma sphuṭa siddhanta by Brahmagupta **(04-Credits)**

Course Outcomes: After the completion of the course, the students shall be able to
CO 1. understand the contribution of Ancient Indian Mathematicians in mathematics.
CO 2. think and develop new ideas in mathematics.
CO 3. get benefit of this course in research.

M.A/M.Sc. Second Semester (Mathematics)

Paper	Course Code	Course Title	Total Credit
I	**MAT-507**	**Fields and Modules**	**4+0**

Course Objectives: The paper of Fields and Modules is introduced to M.Sc. classes for the study of extension field and related results, algebraic and transcendental extension,splitting fields, normal extensions, perfect field, finite fields, galois group, modules, cyclic modules and related results. The main objective of real analysis is that to prepare the students for further research in analysis and modern algebra.

Unit I

Field theory: Extension Fields. Algebraic and transcendental extensions. Splitting Field. Separable and inseparable extensions.

Unit II

Normal extension. Perfect Fields. Finite Fields.

Unit III

Automorphisms of extensions. Galois group. Fundamental theorem of Galois Theory. Construction with ruler and compass. Solution of polynomial equations by radicals.

Unit IV

Modules, Cyclic modules. Simple modules. Semi-simple modules. Schuler's lemma. Free modules. Noetherian and artinian modules. Hilbert basis theorem.

Recommended Books:

1. I.N. Herstein : Topics in Algebra, Wiley Eastern Ltd., New Delhi.
2. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul : Basic Abstract Algebra (Second Edition), Cambridge University Press, Indian Edition.
3. Surjeet Singh and Qazi Zameeruddin: Modern Algebra, Vikas Publishing House. Pvt. Ltd.
4. K.B. Datta : Matrix and Linear Algebra, Prentice Hall of India Pvt. Ltd., New Delhi.
5. S. Kumaresan : Linear Algebra, A Geometric Approach, Prentice Hall of India.
6. A.R. Vasishtha & A.K. Vasishtha : Modern Algebra, Krishna Prakashan Media (P) Ltd., Meerut .
7. H.K.Pathak: Abstract Algebra, Shiksha Sahitya Prakashan.

Course Outcomes: After the completion of the course the student shall be able to

CO 1. think and develop new ideas in this subject.
CO 2. understand the applications of this course in different field of Science and Technology
CO 3. get benefit of this course in various national and international competitive examinations.

Paper	Course Code	Course Title	Total Credit
II	MAT-508	Differential Geometry of Manifolds	4+0

Course Objectives: The paper of Differential Geometry of Manifolds is introduced to M.Sc. classes for the study of Tensor Algebra, Differentiable manifold, Differentiable functions, Differentiable curves, Tangent space, Vector fields, Lie bracket, Principal Fibre Bundle, Covariant differentiation, Torsion, Curvature, Lie derivative, Riemannian Manifold, Exterior algebra and Submanifolds & Hypersurfaces. The main objective of Differential Geometry of Manifolds is that to prepare the students for further research in analysis of differential geometry and analysis.

Unit I

Tensor Algebra: Contravariant and covariant vector. Tensor product of vector spaces, tensor, contravariant, covariant and mixed tensor of second order. Tensor of type (r, s), tensor product of tensors. Algebraic operations, symmetric and skew symmetric tensors, contraction. Definition and examples of differentiable manifold, Differentiable functions, Differentiable curves.

Unit II

Tangent space, Vector fields, Lie bracket. Principal Fibre Bundle, cross section, Linear Frame Bundle, Associated Principal Bundle, Vector Bundles, Bundle Homomorphism, Tangent Bundle, Fundamental Vector Field. Invariant view point of connections. Covariant differentiation.

Unit III

Torsion. Curvature. Parallelism. Difference tensor of two connections. Lie derivative. Riemannian Manifold. Riemannian connection. Riemannian curvature tensor and Ricci tensor. Idenitities of Bianchi. Sectional curvature and Schur's theorem.

Unit IV

Exterior product of two vectors. Exterior algebra of order r. Exterior derivative. Cartans's structural equations. Submanifolds and Hypersurfaces. Normals. Gauss's formula. Weingarten equations.

Books Recommended:

1. R. S. Mishra, A Course in Tensors with Applications to Riemanian Geometry, Pothishala, Allahabad, 1965.

2. Y. Matsushima, Differentiable Manifolds, Marcel Dekker, 1972.

3. B. B. Sinha, An Introduction to Modern Differential Geometry, Kalyani Prakashan, New Delhi, 1982.

4. Y. Talpiert, Differential Geometry with applications to Mechanics and Physics, Marcel Dekkar Inc. 2001.

5. N.J. Hicks, Notes on Differential Geometry, D. Van Nostrand Inc., 1965.

6. U.C.De and A.A.Shaaikh, Differential Geometry of Manifolds, Narosa Publishing House, New Delhi 2007.

7. K.S.Amur ,D.J.Shetty and C.S.Bagewadi, An Introduction to Differential Geometry , Narosa Publishing House, New Delhi 2010.

8. S. Shahshahani, An Introductory Course on Differentiable Manifolds, Dover Publication Inc. New York, 2016.

Course Outcomes: After the completion of the course the student shall be able to

CO 1. understand the basic of this course and think & develop new ideas in this course.

CO 2. demonstrate an intuitive and computational understanding of Tensor Algebra, Differentiable manifold, Riemannian Manifold, Exterior algebra and Submanifolds & Hypersurfaces.

CO 3. enter into wide area of research in differential geometry and its applications in physical sciences and Cosmology. Also get benefit of this course in various national and international competitive examinations.

Paper	Course Code	Course Title	Total Credit
III	**MAT-509**	**Partial Differential Equations**	**4+0**

Course Objectives: The objective of this course is to study the origin, classification, geometrical interpretation and solution of partial differential equations. The additional objective of this course is to prepare the students for research in the field of applied mathematics.

Unit I

Introduction of partial differential equations, formation of partial differential equations, partial differential equations of order one and its classification, Lagrange's partial differential equation of order one and its solution, general methods of solution of Lagrange's equation, method of grouping and method of multipliers, linear partial differential equation of order one with n independent variables.

Unit II

Non-linear partial differential equations of order one, complete integral, particular integral, singular integral and general integral with geometrical interpretations, standard forms of non-linear partial differential equations of order one and their solutions, non-linear partial differential equations of order one reducible to standard forms, compatible system of partial differential of first order, Charpit's and Jacobi's method for solving non-linear partial differential equation of order one.

Unit III

Formation of partial differential equation of higher order, linear homogeneous partial differential equation with constant coefficients of second order, linear non-homogeneous partial differential equation with constant coefficients of second order, Euler-Cauchy partial differential equation.

Unit IV

Linear partial differential equations with variable coefficients, classification of linear partial differential equations of second order and canonical forms, solution of non-linear partial differential equations of second order by Monge's method, method of separation of variables for solving Laplace, diffusion and wave equations.

Books Recommended:

1. V.S.Verma, A Text Book of Partial DifferentialEquations, Neelkamal Prakashan, Gorakhpur, 2019.
2. I.N. Sneddon, Elements of Partial DifferentialEquations, Courier Corporation, 2006.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. learn formation and classification of partial differential equations.
CO 2. solve partial differential equations using different methods.
CO 3. use the method of separation of variables to solve Laplace, diffusion and wave equations.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-510**	**Operations Research**	**4+0**

Course Objectives: Operations research is included in M.Sc. classes due to its wide application in our daily life. Operations research is an important course in applied mathematics because it is very useful in Industry, banking, Defense sector, and Multinational companies etc. to optimize their performance.

Unit I

Inventory Control: Introduction, Classification of Inventory, Economic parameter associated with inventory problems, Deterministic and Probabilistic models with without lead time.

Unit II

Sequencing Problems :Assumptions for seqnencing problem. Processing n jobs on two machines, n jobs on three machines, 2 jobs on m machines, Problem of Replacement, Individuals and Group replacement policies.

Unit III

Network analysis: Basic concepts and definition. Network drawing and analysis Critical path method. Labelling method. Methods based on time estimates to find critical path. Concept of slack and float. Resource levelling and time-cost trade-off analysis. Time-cost optimization procedure. Project crashing. PERT. Requirements for application of PERT technique. Practical limitations in using PERT. Diffferences in PERT and CPM.

Unit IV

Non-Linear Programming: Introduction and defintions. Formulation of non-Linear programming problems, General non-linear programming problems. Kuhn-Tucker conditions, Lagrangian Method, Constrained optimization with equality constraints. Constrained optimization with inequality constaints. Saddle point problems Saddle points and NLPP. Wolfe's and Beale's method to solve Quadratic Progamming problem.

Books Recommended:

1. S.D. Sharma: Operations Research, Kedar Nath Ram Nath & Company.
2. S.S. Rao: Optimization Theory and Applications, Wiley Eastern Ltd., New Delhi.

3. J.K. Sharma: Operations Research – Theory and Applications, Macmillan India Ltd.
4. H.A. Taha: Operations Research – An Introduction, Macmillan Publishing Co., Inc., New York.
5. Kanti Swarup, P.K. Gupta, Man Mohan: Operations Research, Sultan Chand and sons, New Delhi.
6. B.S. Goel, S.K. Mittal: Operations Research, Pragati Prakashan, Meerut.
7. P.K. Gupta, D.S. Hira: Operatons Research – An Introduction, S. Chand & CompanyLtd., New Delhi.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. apply it in different sectors of research field like game theory, job sequencing, network analysis, dynamical programming etc.

CO 2.do their research work in different interdisciplinary areas.

CO 3.get hired by most of the companies as OR technician since companies require OR experts to get maximum output out of minimum resources.

Paper	Course Code	Course Title	Total Credit
V	**MAT-511**	**Fluid Dynamics**	**4+0**

Course Objectives: The paper of Fluid Dynamics is introduced to M.Sc. classes for the study of Fluid motion, Lagrangian and Eulerian methods, Euler's and Lagrange's Equation of continuity and equation of motion, Newton's law of viscosity Navier-Stokes equations of motion, Steady viscous flow between parallel planes. The main objective of Fluid Dynamics is that to prepare the students for further research in applied mathematics and cosmology.

Unit I

General idea of fluids, Properties of fluids, Fluid motion, Kinds of motion, Methods of describing fluid motion, Lagrangian and Eulerian methods, Relation between Lagrangian and Eulerian methods, Streamlines, Path lines, Streak lines, Velocity potential, Vorticity vector, Vortex lines, Boundary surface, Equation of continuity by Euler's and Lagrange's methods, Equivalence between Eulerian and Lagrangian forms of equations of continuity, Equation of continuity in other coordinate systems, Symmetrical forms of equation of continuity.

Unit II

Euler's and Lagrange's equation of motion, Lamb's hydrodynamical equations, Conservative field of force, Euler's equations of motion in cylindrical and Spherical polar coordinates, Equations of motion under impulsive force, Energy equation, Pressure equation, Bernaulli's equation and its applications, Euler's momentum theorem, D'Alermbert's paradox.

Unit III

Newton’s law of viscosity, Kinds of fluids, Nature of stress. Stress components in a real fluid, Symmetry of stress tensor, Transformation of stress components, Stress invariants, Relations between Cartesian components of stress, Rate of strain quadric, Principal stresses, Stoke’s law of viscosity, Relations between stress and rate of strain.

Unit IV

General motion of a fluid elements, Navier-Stokes equations of motion, Steady viscous flow between parallel planes. Steady flow through a tubes of uniform circular cross-sections. Steady flow between concentric rotating cylinders, Diffusion of vorticity, Energy dissipation due to viscosity, Reynold’s number and its physical significance.

Recommended Books:

1. J.K. Goyal and K.P. Gupta: Fluid Dynamics, Pragati Prakashan, Meerut, 2017
2. N. Curle and H. J. Davis: Modern Fluid Dynamics, D. Van Nostrand Company Ltd. London, 1968.
3. G.K. Batchelor: An Introduction to Fluid Dynamics, Cambridge University Press, Cambridge, 2000
4. F. Chorlton: A Text Book of Fluid Dynamics, CBS Publishers and Distributors, New Delhi, 2002.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. effectively write mathematical solutions in a clear and concise manner.

CO 2. demonstrate an intuitive and computational understanding of Fluid motion, Lagrangian and Eulerian methods, Euler’s and Lagrange’s Equation of continuity, Newton’s law of viscosity Navier-Stokes equations of motion, Steady viscous flow between parallel planes.

CO 3. research in applied mathematics, cosmology and use the knowledge in qualifying various competitive exams like CSIR-NET, IAS, and PCS.

Paper	Course Code	Course Title	Total Credit
VI	**MAT-512**	**Project** (the marks of project based on internal evaluation)	**0+4**

Course Objectives: The objective of course is to know introduction to Programming in R/Python/Mathemtica/MATLAB.

Introduction to Programming in R/Python/Mathemtica /MATLAB**:** Introduction computer programming, Data Types, Variables, basic operators, Boolean values, loops, logical operations, Functions, arrays, Data Processing, package, Basic mathematical calculations such as solution of equations, differentiation, integration, solution of differential equations, graph plotting of mathematical functions.

Candidate/Students should write a project based on Mathematical programs on R/ Python/ Mathemtica/ MATLAB from the any one core papers of second semester chosen by students. The mathematical programs would be given by the concern faculty of the core/major papers. **(04-Credits)**

Books Recommended:

1. Eric Matthes, Python Crash Course, William Polock 2016.

2. Amos R. Omondi, Mark Ng'ang'a, and Ryan Marvin, Python Fundamentals: A Practical Guide for Learning Python, Complete with Real-world Projects for You to Explore, PAKCT Publishing (2019).

3. Michael J. C. (2015): An Introduction Using R, 2nd Edition John Wiley and Sons.

4. Zuur, A. F., Leno, E. N. and Meesters, E. H. W. G. (2009): A Beginner’s Guide to R, Springer.

Course Outcomes: After completing the course, the student shall be able to

CO 1. understand the basics of computer programming languages.

CO 2. understand the graph plotting of mathematical functions.

CO 3. understand some advanced computing tools and techniques.

Paper	Course Code	Course Title	Total Credit
# Minor Elective Paper	**MAT-513**	**Statistical Tools in Mathematical Sciences**	**4+0**

Course Objectives: With the help of this paper, the student is equipped with critical statistical thinking, problem solving skills, etc. and apply his/her skill and knowledge in various field of studies including Science, Social Science, Engineering, Commerce and Management etc.

Unit I

Measures of central tendency: Arithmetic mean, geometric mean, harmonic mean, median and mode. Measures of dispersion: Mean Deviation and Variance. Moments, skewness and kurtosis and their measures based on quantiles and moments.

Unit II

Curve fitting, Method of Least squares, fitting of straight-line, second-degree polynomial, power curve, exponential curve etc. Correlation and Rank correlation, Regression Analysis-Regression lines of y on x and x on y, regression coefficients, properties of regressions coefficients.

Unit III

Mathematical expectation and Generating functions. Discrete Probability Distributions: Binomial distribution, Poisson distribution and its mean and variance. Continuous Probability Distributions: Uniform, Exponential, Gamma, Beta, Cauchy, Laplace, Pareto, Weibull, Normal distributions and its mean and variance.

Unit IV

Minimum Spanning tree, Kruskal's and Prim's Algorithm. Null hypothesis and Alternative hypothesis. Critical Region. Errors, Level of significance, Chi-Square test. Control chart for variables: mean, range and standard deviation chart.

Books Recommended:

1. Fundamental of Mathematical Statistics, S.C.Gupta and V.K.Kapoor. Sultan Chand and Sons,2000.

2. Fundamental of Mathematical Statistics, Vol-I,A.M.Goon,M.k.Gupta,B.Dasgupta,World Press, Kolkata,2011.

3. Fundamental of Mathematical Statistics,Vol-II,A.M.Goon,M.k.Gupta,B.Dasgupta,World Press, Kolkata,2013.

4. Introduction to the Theory of Statistics, A.M. Mood, F.A. Graybill, and D.C. Boes, 3rd Edn., Tata McGraw-Hill Pub. Co. Ltd,2011.

Course Outcomes: After the completion of the course, the student shall be able to

CO1: understand basics of statistics including applied aspect for developing enhanced quantitative skills and pursuing higher study and research as well.

CO2: wide ranging application of the subject and have the knowledge of statistics and statistical data.

CO3: analytic and technical skills. By applying the principles of basic statistics, he/she learns to solve a variety of practical problems in science, social science, engineering, Commerce and Management etc.

<u>**M.A/M.Sc. Third Semester (Mathematics)**</u>

Paper	Course Code	Course Title	Total Credit
I	**MAT-514**	**Number Theory**	**4+0**

Course Objectives: The paper of Number Theory is introduced to M.Sc. classes for the study of Division algorithm, Greatest common divisor, Euclid's lemma, Euclidian Algorithm, Fundamental theorem of arithmetic, Euclid's theorem, Congruence's, Euler's –phi function, Chinese remainder theorem, Cryptography, Arithmetic functions, Quadratic congruence, Perfect number, Fermat number, Fibonacci numbers. The main objective of Number Theory is that to prepare the students for further research in Number Theory and coding theory.

Unit I

Divisibility: Some basic terms and properties, Division algorithm, Common divisor, Greatest common divisor (gcd), Theorems on gcd, Euclid's lemma, relatively prime, Euclidian Algorithm, least common multiple (lcm), Theorems on lcm, Fundamental theorem of arithmetic, Euclid's theorem, Linear Diophantine Equation $a\,x + b\,y$ = c and its solutions.

Unit II

Congruences: Basic properties and theorems of congruences, Residue and complete residue system, Reduced residue system, Fermat's theorem, Wilson theorem, Converse of Wilson theorem, Linear Congruences, Chinese remainder theorem, Method of solution of congruences, Binary and Decimal Representation of Integers.

Unit III

Cryptography: Introduction of cryptography, Block Diagram of cryptography, some simple cryptosystems, additive cipher, shift cipher, caeser cipher, affine cipher, auto key cipher, play fair cipher, hill cipher or enciphering matrices, vigenere cipher, vernam cipher, rail fence cipher, simple columnar cipher, simple columnar with multiple rounds cipher.

Unit IV

Arithmetic functions or Number-theoretic functions: The function τ and σ, Multiplicative function, Euler's $\phi -$function, Euler's theorem, Moebius $\mu -$function, Moebius inversion formula, Greatest integer function. Quadratic congruence: Quadratic congruence, Quadratic residues, Euler's criterion. Perfect number, Fermat number, Fibonacci sequence and numbers.

Books recommended:

1. Niven and Zuckermann: An Introduction to the theory of numbers, Wiley Eastern Ltd.
2. Ireland & Rosen, A Classical Introduction to Modern Number Theory, Springer
3. Tom Apostol, Introduction to Analytic Number theory, Narosa Publications, New Delhi
4. Delfs, H., Knebl, H., Introduction to Cryptography, Springer.
5. Koblitz, N., Algebraic Aspects of Cryptography, Springer.
6. Serre, J.P., A Course in Arithmetic, Springer.
7. Cassels, J.W.S., Frolich, A., Algebraic Number Theory, Cambridge.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. understand the basic of this course and think & develop new ideas in this course.

CO 2.do research in number theory and coding theory.

CO 3.get benefit of this course in various national and international competitive examinations.

Paper	Course Code	Course Title	Total Credit
II	MAT-515	Functional Analysis -I	4+0

Course Objectives: (i) The main objective of the course at master's level is that functional analysis embodies the abstract approach to analysis.
(ii) It brings out the essence of a problem by clearing out unnecessary details and gives a unified treatment of apparently unrelated topics.
(iii) It originally grew out of the study of function spaces. The theoryof Banach spaces developed in parallel with the general theory of linear topological spaces.

Unit I

Normed linear spaces, Banach spaces, their examples including R^n ,C^n , l_p (n), $1 \leq p < \infty$, c0, c, l_p, $1 \leq p < \infty$, P [a,b], C[a,b]. Joint continuity of addition and scalar multiplication. Summable sequences and completeness. Subspaces, Quotient spaces of normed linear space and completeness, completion of normed spaces.

Unit II

Continuous and bounded linear operators and their basic properties. Normed linear space of bounded linear operators and its completeness. Equivalent norms. Finite dimensional normed spaces and compactness.

Unit III

Isometric isomorphism, Topological isomorphism. Riesz Theorem, Open mapping theorem and its simple consequences. Product normed space. Closed graph theorem. Uniform boundedness. Banach-Steinhaus theorem. Adjoint of bounded Linear operators.

Unit IV

Bounded linear functionals Dual spaces. Form of dual spaces $(R^{n)})^*$, $(C^n)^*$,c_o^*, l_1^*, l_p^*, $1< p < \infty$. Hahn- Banach theorem for real and complex normed linear spaces and its simple consequences. Embedding and Reflexivity.

Books Recommended:

1. P.K. Jain, O.P. Ahuja and K. Ahmad: Functional Analysis, New Age International (P)Ltd. and Wiley Eastern Ltd., New Delhi, 1997.
2. B. Choudhary and S. Nanda: Functional Analysis with Applications, Wiley Eastern Ltd., 1989.
3. I.J Maddox: Functional Analysis, Cambridge University Press (1970).
4. B.V.Limaye: Functional Analysis,New Age International Publications, New Delhi.
5. K. Chandrashekhara Rao. Functional Analysis, Narosa Publishing House, New Delhi
6. W.Rudin: Functional Analysis, TMH, New Delhi .
7. H.K.Pathak: Functional Analysis withApplications, Siksha Sahitya Prakashan, Merrut

Course Outcomes:

CO 1. Since the functional analysis provides a major link between mathematics and its applications. Students may help scientists and enlightened engineers in their work after completing this course.

CO 2. Course provides a powerful tool to discover solutions to problems occurring in physics, statistics, engineering, economics, physiology, medicine, ecology and agro-industry etc.

CO 3. Course study will help students to determine the significance of functional analysis in modern applied and computational mathematics.

Paper	Course Code	Course Title	Total Credit
III	**MAT-516**	**Mathematical Modelling**	**4+0**

Course Objectives: The objective of this course is to enable students to know about mathematical modelling, its need and different tools to formulate mathematical models representing real- world phenomenon. The students will be able to analyze them and make predictions about behavior of the real-world system under study.

Unit I

Mathematical modelling, simple situations requiring mathematical modelling, tools, techniques and classification of mathematical models, characteristics of mathematical models, limitations of mathematical modelling, mathematical modelling using various mathematical disciplines.

Unit II

Mathematical modelling through differential equations, human population and biological growth, growth and decay models, microbes and microbial kinetics, microbial growth in chemostat, stability of steady states for chemostat, growth of microbial populations.

Unit III

Mathematical modelling through difference equations, introduction to difference equations, formation and solution of difference equations, linear difference equations, simultaneous difference equations with constant coefficients, solution of linear difference equations by Laplace transform and Z-transform, solution of nonlinear difference equations reducible to linear difference equations, stability theory for difference equations, applications of difference equations in population dynamics.

Unit IV

Single species: non age and age structured models, simple logistic models, physical basis of logistic model, Smith's model, generalized logistic model, difference equation for logistic model, logistic model for a non-isolated population, BLL model, some Leslie matrix and its eigen values and eigen vectors.

Books Recommended:

1. J.N. Kapur: Mathematical Modelling, New Age International (P) Limited, NewDelhi, 2007.

2. J.N. Kapur: Mathematical Models in Biology and Medicine, Affiliated East-West PressPvt. Ltd., New Delhi,1985.

3. J. Mazumdar: An Introduction to Mathematical Physiology and Biology, Cambridge UniversityPress, 1999.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. assess and articulate what type of modelling techniques are appropriate for a system.

CO 2. construct mathematical models in real-world biological phenomenon.

CO 3. predict the behavior of a system based on the analysis of its mathematical model.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-517**	**Advanced Topology**	**4+0**

Course Objectives: The objective of this paper is to study Characterization of connected sets in terms of open sets and closed sets, Directed sets, nets and subnets filter, filter base and subbase, Tychonoff product topology interms standard subbase and its characterizations in terms of projection maps, continuous functions, Product of T_0,T_1,T_2, spaces, Connectedness and compactness, first and second countability for product spaces. Homotopy of paths. Also to prepare the students for further research in analysis and differential geometry.

Unit I

Characterization of connected sets in terms of open sets and closed sets. Closure of a connected set. Union of connected sets. Connected sets in R. Continuity of a function and connectedness. Components and partition of space. Path connected space.

Unit II

Inadequacy of sequential convergence. Directed sets, nets and subnets and their examples Convergence of a net, charaterisation of open sets, closed sets, closure, cluster point and limit pointof a set in terms of net convergence. Hausdorffness and continuity of a function in terms of nets.

Unit III

Definition of filter and its examples. Neighborhood filter. Comparison of filters. Filter base and subbase. Convergence of a filter. Ultrafilters. Continuous functions and filters.Net based on filterand filter based on net. Quotient topology, quotient space, quotient map, quotient space X/R, Finiteproduct space, projection mapping.

Unit IV

Tychonoff product topology in terms standard subbase and its characterizations in terms of projection maps, continuous functions, Product of T_0,T_1,T_2, spaces. Connectedness and compactness, first and second countability for product spaces. Homotopy of paths.

Books Recommended:

1. George F. Simmons : Introduction to Topology and Modern Analysis, Mc Graw-Hill Book Company 1963.
2. J.L. Kelley : General Topology, Van Nostrand, Reinhold Co., New York 1995.
3. K.D. Joshi : Introduction to General Topology, Wiley Eastern Ltd., 1983.
4. James R Munkres : Topology, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
5. S. Willard : General Topology Addison-Wesley, Reading, 1970.

Course Outcomes: After the completion of the course, the student shall be able to
CO 1. understand the basic of this course and think & develop new ideas in this course.
CO2. know about Characterization of connected sets in terms of open sets and closed sets, Directed sets, nets and subnets filter, filter base and subbase , Tychonoff product topologyin terms standard subbase and its characterizations in terms of projection maps, continuous functions, Product of T_0,T_1,T_2, spaces, Connectedness and compactness, first and secondcountability for product spaces. Homotopy of paths.
CO3.get involved in wide area of research in analysis and differential geometry.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-518**	**General Relativity and Gravitation**	**4+0**

Course Objectives:
(i)The objective of this paper is to study Einstein's theory of gravitation (General theory of Relativity).
(ii)All of modern physics is based on the theory of relativity and quantum mechanics. To provide the students with sufficient exposure to general theory of relativity and gravitation that to understand the physical universe.
(iii)Improving the understanding of space time and physical phenomenon of the universe.

Unit I

Space time, Curved Space time, Riemannian metric, Riemannian curvature tensor, Geodesic and geodesic deviation, Conformal curvature tensor, Bianchi Identities, Einstein Tensor.

Unit II

Introduction to General Relativity, Principal of Equivalence, Principal of General covariance, Mach's Principle, Newtonian approximation of equation of motion. Einstein's field equation, Gravitational field in empty space time.

Unit III

Schwarzschild exterior solution, Singularities in Schwarzschild line element, Kruskal-Szekers coordinate, Isotropic form of Schwarzschild exterior line element, Birkhoff's theorem.

Unit IV

Planetary orbits. The Crucial Tests of General Relativity, Energy momentum tensor, Formula for energy momentum tensor for perfect fluid, dust, Vaidya metric.

Books Recommended:
1. K. D. Krori : Fundamentals of Special and General Relativity; PHI Publication, 2010.
2. S. R. Roy and Raj Bali : Theory of Relativity; Jaipur Publishing House, 2008.
3. Steven Weinberg : Gravitation and Cosmology : Principles and applications of General Relativity; Wiley Publ.,2005.
4. J. V. Narlikar : An Introductions to Relativity; Cambridge University Press, 2010.
5. I.B. Khriplovich : General Relativity; Springer Science + business media, 2005.

Course Outcomes: After the completion of the course, the student shall be able to

CO1. understand the basis of Einstein's gravitational field equations.
CO2. provide the solutions of Einstein's gravitational field equations which relates the geometry and physics of physical system.
CO 3. know the importance of this theory in solving the problem of universe with the differential geometry and geometric structures.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-519**	**Summability Theory and Approximation**	**4+0**

Course Objectives: The main objectives are:

(i)To study Special methods of summation: Nörlund means, Regularity and Consistency of Nörlund means, summation of series by arithmetic means.

(ii) To understand Approximation of functions by trigonometric polynomials.

(iii)To study functions of Lip α , Lip(α, r) and Lip(ξ(t),r) classes , degree of approximation of functions by (C,1), (E,1), (C,1)(E,1), (N, p_n) means of their Fourier Series.

Unit-I

Summation of a series by Arithmetic Mean, Special methods of summation: Nörlund means, Regularity and Consistency of Nörlund means, Inclusion, Equivalence.

Unit-II

Euler's means, Abelian means, Riesz's typical means., Arithmetic means: Hölder's means, simples theorems concerning Hölder summability.

Unit-III

Cesàro means, means of non-integral orders, simple theorems concerning Cesàro summability , Cesàro and Abel summability, Cesàro means as Nörlund means, Tauberian theorems for Cesàro summability.

Unit-IV

Approximation of functions by trigonometric polynomials, Best approximation, functions of Lip α , Lip(α, r) and Lip(ξ(t),r) classes , degree of approximation of functions by (C,1), (E,1), (C,1)(E,1), (N, p_n) means of their Fourier Series.

Recommended Books:

1. E.C. Titchmarsh: A Theory of Functions, Oxford University Press, 1939.

2. 2. A Zygmund: Trigonometric series Vol. I, The University Press, Cambridge 1959.

3. 3. G. H. Hardy: Divergent series, The Clarendon Press, Oxford, 1949.

Course Outcomes: After the course the students will be able to

CO 1. understand the basics of summability theory.
CO 2. to understand the use of this course in different field of mathematical Analysis.
CO 3. to think and develop new ideas in Approximation theory.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-520**	**Hydro Dynamics**	**4+0**

Course Objectives: To study Lagrange's stream function, Two-dimensional source, sink, doublet, Theorem of Blasius, general motion of cylinder, ellipse and sphere, Stoke's function, Irrotational motion, Kelvin's proof of performance. Motion due to circular and rectilinear vertices.

Unit I

Flow and circulation, Kelvin's circulation theorem, Two dimensional motion, Lagrange's stream function, Complex potential, Source and sink, Complex potential due to source and sink, Doublet, Complex potential due to doublet, Images, Image of a source with respect to a straight line, Image of a doublet with respect to straight line, Circle theorem of Milne-Thomson, Image of a source in a circle, Image of a doublet in a circle, Blasius Theorem.

Unit II

General motion of the cylinder in two dimensions, Motion of a circular cylinder in a uniform stream, The motion in the case of a liquid streaming past a fixed circular cylinder, Initial motion between two coaxial circular cylinders, Kinetic energy of liquid, Equation of motion of a circular cylinder without circulation, Circulation about a circular cylinder, Streaming and circulation about a fixed circular cylinder.

Unit III

Elliptic coordinates, Motion of a moving elliptic cylinder, Motion of a fixed elliptic cylinder, Motion of a rotating elliptic cylinder, Kinetic energy of the liquid contained in rotating elliptic cylinder, Streaming past a fixed elliptic cylinder, Circulation about an elliptic cylinder.

Unit IV

Motion of a sphere through a liquid, Liquid streaming past a fixed sphere, Equation of motion of a sphere, Problem of initial motion of spheres, Stoke's stream function, Irrotational motion, Vortex lines, Vortex motion, Vortex tube, Vortex filament and its properties, Strength of vortex, Complex potential due to a rectilinear vortex, Rectilinear vortices with circular cross-section.

Books Recommended:

1. J.K. Goyal and K.P. Gupta: Fluid Dynamics, Pragati Prakashan, Meerut, 2017

2. N. Curle and H. J. Davis: Modern Fluid Dynamics, D. Van Nostrand Company Ltd. London, 1968.

3. B.G. Verma: Hydrodynamics, Pragati Prakashan, Meerut, 1995.

Course Outcomes: After the completion of the course, the student will be shall to

CO 1. have better understanding of hydrodynamical motion whichplay a very important role in applied sciences and physical problems.

CO 2.do research in applied mathematics and variousphysical problems.

CO 3.solve problems related to the course in various competitive exams like IAS, PCS, faculty exams of higher education etc.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-521**	**Numerical Solution of Differential Equations**	**4+0**

Course Objectives: The objective of this paper is to study numerical solution of differential equations and system of nonlinear equations. Also introduce students to Runge- Kutta method for time dependent problem, boundary value problems using finite difference, finite element and spectral methods. The main objective of Numerical Solution of Differential Equations is that to prepare the students for further research in applied mathematics.

Unit I

Numerical Solution of parabolic partial differential equations (PDE) in one space: two and three levels explicit and implicit differences schemes. Convergence and stability analysis.

Unit II

Numerical solution parabolic PDE of second order on two spaces dimension: Implicit methods, alternating direction implicit (ADI) methods. Non-linear initial BVP (boundary valued problems). Differences schemes for parabolic PDE in spherical and cylindrical coordinate systems in one dimension.

Unit III

Numerical solution of hyperbolic PDE in one and two spaces dimension: explicit and implicit schemes: ADI methods. Differences schemes for first order equations, Numerical solutions of elliptical equations

Unit IV

Approximations of Laplace Solutions of Dirichlet, Neuman and mixed type problems. Finite element methods: Linear, triangular elements and rectangular elements.

Recommended Books:

1. M. K. Jain, S.R.K. Iyenger and R. K. Jain: Computational Methods for Partial differential equations, Wiley Eastern, 1994.

2. M. K. Jain, Numerical Solution Differential Equation, 2nd Edition, WileyEastern.

3. S. S. Sastry, Introductory Methods of Numerical analysis, Prentice-Hall of India, 2002.

4. D .V. Griffiths and I. M. Smith, Numerical Methods of Engineers, Oxford University Press, 1003.

5. C. F. General and P.O. Wheatley: Applied Numerical Analysis, Addison-Wiley, 1998.

6. B. S Grawal: Higher Engineering Mathematics , Khanna Publication.

7. J. N. Reddy: Introduction to Finite Element Method.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. make intelligent choices of methods for specific problems.

CO 2. have knowledge of state of the art numerical method in the field.

CO 3. use the numerical methods in performing calculations of real world mathematical problems.

Paper	Course Code	Course Title	Total Credit
V	MAT-522	Discrete Mathematics	4+0

Course Objectives: Discrete Mathematics is the study of mathematical structure that are countable otherwise district and separable. Concepts of discrete mathematics are useful in studying and describing abreast and problems in computer science

Unit 1

Semigroups & Monoids: Definition and examples of Semigroups and Monoids. Homomorphism of Semigroups and Monoids. Congruence relation and Quotient Semigroups. Subsemigroup and Submonoids. Direct products. Basic homomorphism theorem.

Unit II

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.

Unit III

Boolean Algebras: Boolean Algebras as Lattices, Various Boolean Identities. The Switching Algebra example. Subalgebras. Direct Products and Homomorphisms. Join-irreducible elements, Atoms and Minterms. Boolean Forms and their Euivalence.

Unit IV

Graph Theory: Definition of Graphs, Paths, Circuits, Cycles & Subgraphs. Induced Subgraphs. Degree of a vertex. Connectivity. Planar graphs and their properties. Trees. Euler's Formula for connected planar graphs.

Books Recommended:

1. C.L. Liu: Elements of Discrete Mathematics (Second Edition), McGraw Hill, International Edition, Computer Science Series, 1986.

2. J.P. Tremblay & R. Manohar: Discrete Mathematical Structures with Applications to Computer Science, McGraw-Hill Book Co., 1997.

3. N. Dew. Graph Theory with Application to Engineering and Computer Sciences, Prentice Hall of India.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. study the significance of discrete mathematics as a modern trend in world-wise era of computer science especially Cryptography, Rational Databases, Logistics Computer algorithm, robotics, Google maps, etc.

CO 2.apply knowledge of discrete mathematics in Computer Networking in many Government and Private agency.

CO 3. solve problems related to the course in various competitive exams like IAS, PCS, faculty exams of higher education etc.

Paper	Course Code	Course Title	Total Credit
V	MAT-523	Mathematical Epidemiology	4+0

Course Objectives: The overall objective of this course is to enable students to build mathematical models of some diseases, analyze them and make predictions about behavior of diseases. Moreover, objective of this course is to prepare the students for research in the field of mathematical epidemiology.

Unit I

Autonomous system, phase plane, critical points, types of critical points, stability of critical points in linear systems, asymptotic stability, stability by Lyapunov's direct method, simple critical points of non-linear systems.

Unit II

Introduction of mathematical epidemiology, need, scope and limitations of mathematical epidemiology, basic terminologies, basics of epidemic, endemic and pandemic, basic reproduction number, effective reproduction number and contact number, prevalence and incidence of a disease, SI model, SIS model with constant coefficient, SIS model with constant number of carriers.

Unit III

Basic SIR epidemic model, threshold for SIR epidemic, basic SIR endemic model, SIR endemic model with no disease related death, SIR endemic model with disease related death, SIR model with vaccination, SIRS, SEIR and SEIRS epidemic models.

Unit IV

Immunology and AIDS: modelling the transmission dynamics of HIV, Anderson first model, Anderson improved model, spread of Tuberculosis (TB), mathematical modelling of transmission of TB, emergence and spread of COVID-19 pandemic, mathematical modelling of COVID-19 transmission, concomitant diseases.

Books Recommended:

1. J.N. Kapur: Mathematical Modelling, New Age International (P) Limited, New Delhi, 2007.
2. J.N. Kapur: Mathematical Models in Biology and Medicine, Affiliated East-West Press Pvt. Ltd., New Delhi, 1985.
3. J. Mazumdar: An Introduction to Mathematical Physiology and Biology, Cambridge University Press, 1999.
4. Nicholas F. Britton: Essential Mathematical Biology, Springer, 2003.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. assess and articulate the appropriate modelling techniques for the spread of a disease in the system.

CO 2. Construct and analyze mathematical models in epidemiology and analyze it.

CO 3. make predictions of the behavior of the diseases based on the analysis of its mathematical model. analyze them and make predictions about behavior of diseases.

Paper	Course Code	Course Title	Total Credit
V	**MAT-524**	**Complex Manifolds**	**4+0**

Course Objectives: The paper of Complex Manifolds is introduced to M.Sc. classes for the study of Almost Complex Manifolds, F-connection, half symmetric connection, Almost Hermit Manifolds, Kaehler Manifolds and Nearly Kaehler Manifolds, Curvature identities, almost analytic vectors. The main objective of Complex Manifolds is that to prepare the students for further research in analysis of differential geometry, structure of differentiable manifold and analysis.

Unit I

Almost Complex Manifolds: Elementary notions, Nijenhuis tensor Eigen values of F, Integrability conditions, Contravariant and covariant analytic vectors, F-connection, half symmetric connection.

Unit II

Almost Hermit Manifolds: Definition, Almost analytic vector fields. Curvature tensor. Linear connections.

Unit III

Kaehler Manifolds: Definition. Curvature tensor. Affine connection. Properties of projective, conformal, concircular and conharmonic curvature tensors. Contravariant almost analytic vector.

Unit IV

Nearly Kaehler Manifolds: Introduction, Curvature identities, almost analytic vectors.

Books Recommended:

1. R.S. Mishra: Structure on differentiable manifold and their application, Chandrama Prakashan, Allahabad, 1984.

2. K. Yano and M. Kon: Structures of Manifolds, World Scientific Publishing Co. Pvt. Ltd., 1984.

3. U.C.De and A.A.Shaaikh, Complex and Contact Manifolds, Narosa Publishing House, New Delhi 2009.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. investigate basic structure of differentiable manifold.

CO 2. demonstrate an intuitive and computational understanding of Differentiable manifold, Riemannian Manifold, Almost Complex Manifolds, F- connection, half symmetric connection, Almost Hermit Manifolds, Kaehler Manifolds and Nearly Kaehler Manifolds.

CO 3.get a wide area of research in differential geometry and analysis of differential geometry.

Paper	Course Code	Course Title	Total Credit
V	MAT-525	Riemannian Geometry	4+0

Course Objectives: The paper of Riemannian Geometry is introduced to M.Sc. classes for the study of Generalised convariant differentiation , Gauss's formulae, Curvature of a curve in a hypersurface, Normal curvature, Mean curvature, Change from one set of normal to another, Curvature of a curve in subspace, Infinitesimal transformation, Hyperplanes, Hyperspheres, Geodesics in a space. The main objective of Riemannian geometry is that to prepare the students for further research in differential geometry and Riemannian geometry.

Unit 1

Unit normal. Generalised convariant differentiation. Gauss's formulae. Curvature of a curve in a hypersurface. Normal curvature. Mean curvature. Principal normal curvature. Lines of curvature. Conjugate and asymptotic directions. Tensor derivative of the unit normal. Gauss characteristic equation and Mainardi-Codazzi equations. Totally geodesic hypersurfaces.

Unit II

Unit normals. Gauss's formulae. Change from one set of normals to another. Curvature of a curve in subspace. Conjugate and asymptotic directions. Generalisation of Dupin's theorem. Derived vector of a unit normal. Lines of curvature for a given normal.

Unit III

Infinitesimal transformation. The notion of Lie derivative. Lie derivative of metric tensor and connection. Motion and affine motion in Riemannian spaces.

Unit IV

Hyperplanes. Hyperspheres. Central quadric hypersurfaces. Reciprocal quadric hypersurfaces. Conjugate radii. Any hypersurface in Euclidean spaces. Riemannian curvature of a hypershpere. Geodesics in a space of positive constant curvature.

Books Recommended:

1. C.E. Weatherburn: An Introduction to Riemannian Geometry and the Tensor Calculus, Cambridge University Press, 1966.

2. K. Yano: The Theory of Lie Derivatives an its Applications, North Holland Publishing Company, Amsterdam,1957.

3. R. S. Mishra: A Course in Tensors with Applications to Riemannian Geometry, Pothishala (Pvt.) Ltd., 1965.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. understand the basic of this course and think & develop new ideas in this course.

CO 2. know Generalised convariant differentiation , Gauss's formulae, Curvature of a curve in a hypersurface, Normal curvature, Mean curvature, Change from one set of normals to another. Curvature of a curve in subspace, Infinitesimal transformation, Hyperplanes, Hyperspheres, Geodesics in a space .

CO 3.to do research in differential geometry & Riemannian Geometry.

Paper	Course Code	Course Title	Total Credit
V	MAT-526	Hydro Statics	4+0

Course Objectives: The objective of this paper is to study fluid pressure, surface of equal pressure, elastic fluids, rotating fluids, the equilibrium of floating body etc. Also to prepare the student for further research in Hydrostatics.

Unit I

Fluid Pressure: Equation of pressure, Necessary condition of equilibrium, surface of equal pressure, curves of equal pressure and density, Elastic fluids, Rotating fluids.

Unit II

Resultant Pressure and Centre of pressure: Formula for Centre of pressure, geometrical position of centre of pressure, locus of centre of pressure, resultant pressure on curved surfaces.

Unit III

The equilibrium of Floating Bodies: Conditions of equilibrium, Principle of potential energy and Work done, Surface of Buoyancy.

Unit IV

Stability of Floating Bodies: Meta centre, Conditions of stability, Work done in small displacement, floating vessel containing liquid, Stability in Heterogeneous Liquid.

Books recommended:

1. Bhu Dev Sharma: Hydro – statics, Kedar Nath Ram Nath.
2. M. Ray, H. S. Sharma : A Text Book of Hydro- statics, S. Chand
3. Rahman: Hydrostatics, Savera Publishing House.
4. N. Inoue, M. Nishihara: Hydrostatic Extrusion: Theory and Applications, Springer
5. S.L. Loney: Mechanics and Hydrostatics for beginners, Cambridge University Press.

Course Outcomes: After the completion of the course, the student will be able to

CO 1.understand the basic of this course and think and develop new idea in this course.
CO 2.know about fluid pressure, elastic fluids, rotating fluids, resultant pressure and center of pressure, the equilibrium of floating bodies, metacentre etc.
CO 3.do research in Hydrostatics and applied mathematics.

Paper	Course Code	Course Title	Total Credit
VI	**MAT-527**	**Project** (the marks of project based on internal evaluation)	**0+4**

Course Objectives: The objective of course is to know introduction to Mathematical type setting on LaTeX and Advance Programming in R/python/Mathematica/MATLAB.

Mathematical type setting on LaTeX: Sample Document, Type Style, Tables, Equation Environments, Fonts, Theorem-like Environments, Math Styles, Document Classes and the Overall Structure, Titles for Documents, Sectioning Commands, Packages, Making a Bibliography, Scientific writing, Beamer. Advance Programming in R/python/Mathematica/MATLAB.

Candidate/Students should write a project based on Mathematical programs on R/ Python/ Mathemtica/ MATLAB from the any one core or elective papers of third semester chosen by students. The mathematical programs would be given by the concern faculty of the core/major papers or discipline specific elective/ elective papers. **(04-Credits)**

Books Recommended:

1. Eric Matthes, Python Crash Course, William Polock 2016.

2. Amos R. Omondi, Mark Ng'ang'a, and Ryan Marvin, Python Fundamentals: A Practical Guide for Learning Python, Complete with Real-world Projects for You to Explore, PAKCT Publishing (2019).

3. Michael J. C. (2015): An Introduction Using R, 2nd Edition John Wiley and Sons.

4. George Grätzer, More Math Into LaTeX, 4th Edition, Springer (2016).

Course Outcomes: After completing the course, the student shall be able to

CO 1. understand the basics of computer programming languages and LaTeX.

CO 2. understand the graph plotting of mathematical functions.

CO 3. understand some advanced computing tools and techniques.

M.A/M.Sc. Fourth Semester Based on CBCS (Mathematics)

Paper	Course Code	Course Title	Total Credit
I	**MAT-528**	**Measure Theory**	**4+0**

Course Objectives: A measure is a generalization of the concept of length, area and volume. The main objective of this paper is that to prepare the students for further research in measure theory and analysis.

Unit I

Measurable set, Lebesgue's outer and inner measure and its properties. Lebesgue integral and its properties. Length of an interval and Lebesgue outer measure. Lebesgue measurable sets in R and σ-algebra of Lebesgue measurable sets in R Lebesgue measurability of open sets, closed sets and Borel sets. Labesgue measure on R. Example of a Non-Lebesgue measurable set. Cantor's set and its Labesgue measure. General outer measure. Caratheodory's definition of measurable sets. σ-algebra of measurable sets.

Unit II

Definition of a measure. Measurable space and a measure space. Definition of a measurable function. Equivalent conditions for measurable function. Sum and product of measurable functions. Composition of a measurable and a continuous function. Sequences of measurable functions. Measurability of supremum function, infimun function, limit superior function, limit inferior function and limit function.

Unit III

Simple measurable functions and their properties. A non-negative measurable function as the limit of a sequence of non-negative simple measurable functions. Concept of almost everywhere (a.e.). Lebesgue theorem. Convergence in Measure and its properties. F. Riesz theorem and Egorov theorem. Convergence almost everywhere, almost uniform convergence and their inter-relations.

Unit IV

Lebesgue Integration of a simple measurable function on R and its properties. Lebesgue Integration of a bounded measurable function on a set E with finite Lebesgue measure and its properties. Bounded convergence theorem, Fatou's lemma, Lebesgue monotone convergence theorem, Lebesgue dominated convergence theorem, Lebesgue integration and Riemann integration. Integration on a measure space. Lebesgue integral of general measurable function and its properties.

Books Recommended:

1. Walter Rudin, Principle of Mathematical Analysis (3rd edition) McGraw-Hill Kogakusha, International Student Edition, 1976.
2. P. R. Halmos, Measure Theory, Van Nostrand, 1950.
3. G. de Barra, Measure Theory and Integration, Wiley Eastern, 1981.
4. P. K. Jain and V. P. Gupta, Lebesgue Measure and Integration, New Age International, New Delhi, 2000.
5. R. G. Bartle, The Elements of Integration, John Wiley, 1966

Course Outcomes: After the completion of the course, the student will be able to
CO 1. apply measure theory in Statistics to understand deeper issue in probability theory.
CO 2. understand applications of measure theory in economics.
CO 3. solve problems related to the course in various competitive exams.

Paper	Course Code	Course Title	Total Credit
II	**MAT-529**	**Functional Analysis-II**	**4+0**

Course Objectives: (i) The main objective of this course at master's level is that functional analysis embodies the abstract approach to analysis.
(ii) This course is an abstract vector space possessing the structure of an innerproduct that allows length and angle to be measured.
(iii) Since the course embodies abstract approach in analysis. Students will study classes of functions rather than an individual function.

Unit I

Inner product spaces, their basic properties and examples, Schwartz inequality. Norm induced by inner product, Continuity of inner product, Hilbert spaces and their examples. Parallelogram equality, polarization identity. Characterization of inner product in terms of norm.

Unit II

Orthogonal vectors. Orthogonal complement. Projection theorem. Projection operators. Orthogonal sets and their advantage over its linearly independent sets. Complete orthonormal sets. Bessel's generalized inequality. Parseval's Relation.

Unit III

Grahm-Schmidt orthogonalization process. Fourier series representation. Separable Hilbert spaces and their examples. Bounded linear functionals on Hilbert spaces. Riesz-Frechet representation theorem. Dual spaces. Inner product structure of dual spaces. Reflexivity of Hilbert spaces.

Unit IV

Hilbert adjoint operators. Shift operators. Special cases of Hilbert adjoint operoters self adjoint operators, positive operator, normal operators, unitary operators. Orthogonal projection operators. Eigen Values of Linear Operator. Spectrum of a Bounded Linear Operator. Spectral properties of bounded linear operators.

Books Recommended:

1. P.K. Jain, O.P. Ahuja and K. Ahmad: Functional Analysis, New Age International (P) Ltd. and Wiley Eastern Ltd., New Delhi, 1997.
2. B. Choudhary and S. Nanda: Functional Analysis with Applications, Wiley Eastern Ltd., 1989.
3. I.J Maddox: Functional Analysis, Cambridge University Press (1970).
4. B.V.Limaye: Functional Analysis,New Age International Publications, New Delhi.
5. K. Chandrashekhara Rao. Functional Analysis, Narosa Publishing House, New Delhi
6. W.Rudin: Functional Analysis, TMH, New Delhi.
7. H.K.Pathak: Functional Analysis with Applications, Siksha Sahitya Prakashan, Merrut.

Course Outcomes:
CO 1. After completing the course students are able to determine the existence, uniqueness and regularity of equations and inequalities
CO 2. It highlights the interplay between algebraic structures and distance structures.
CO 3. Students are able to understand the application of Hilbert spaces in Mathematics and Physics. They can apply the concept of Hilbert spaces in solving partial differential equations and in studying Fourier analysis, etc.

Paper	Course Code	Course Title	Total Credit
III	**MAT-530**	**Classical Mechanics**	**4+0**

Course Objectives: The objective of this paper is to study about rigid bodies and basic concepts about them, the students will get awareness about generalized coordinates, different types of dynamical systems and Eulerian, Lagrangian and Hamiltonian approach to study the dynamical systems. Students will have knowledge about small oscillations and canonical transformations.

Unit 1
Rigid bodies as system of particles, general displacement of a rigid body, abstract theory of small displacement, use of theory of small displacement, concept of angular velocity, theorem of relative angular velocities, rate of change of any vector in moving frame of reference, acceleration of a particle in polar coordinates, motion of a particle in rotating frame, motion of a rigid body in rotating frame.

Unit 2

Kinetic energy and angular momentum of rigid body rotating about its fixed point. Eulerian approach to rigid body motion, Euler dynamical equations of motion for finite and impulsive forces, Eulerian angles and geometrical relations, instantaneous axis of rotation, invariable line, locus of invariable line.

Unit 3

Dynamical systems and its classification, generalized coordinates, kinetic energy, momentum, force, Lagrange equations of motion under finite forces, cyclic coordinates, Routhian function, ignoration of coordinates, conservation of energy by Lagrangian approach, Lagrangian approach to solve dynamical problems, Lagrange equations for constrained motion under finite forces, Lagrange equations of motion under impulses, theory of small oscillations.

Unit 4

Hamiltonian approach and its applications in dynamical system, conservation of energy by Hamiltonian approach, natural motion, variation of action, Hamilton principle and principle of least action. Hamilton-Jacobi equation of motion, phase space, canonical transformations, conditions of canonicality, cyclic relations, generating functions, Poisson brackets, Poisson first and second theorems, Poisson Jacobi identity, invariance of Poisson bracket.

Books Recommended:
1. E. A. Milne, Vectorial Mechanics, Methuen & Co. Ltd., London, 1965.
2. A. S. Ramsey, Dynamics, Part II, CBS Publishers & Distributors, Delhi, 1985.
3. N. C. Rana and P.S. Joag, Classical Mechanics, Tata McGraw-Hill, 1991.

4. H. Goldstein, Classical Mechanics, Narosa, 1990.
5. J. L. Synge and B. A. Griffith, Principles of Mechanics, McGraw-Hill, 1991.

Course Outcomes: After the completion of the course, the student shall be able to
CO 1. understand the Eulerian, Lagrangian and Hamiltonian approach of studying the dynamical systems.
CO2.apply the formalisms of analytical dynamics to practical examples of small oscillations.
CO3.apply the related mathematical methods such as coordinate transformations and variational methods to study real life problems.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-531**	**Fourier Analysis**	**4+0**

Course Objectives: The main objectives are:
(i) To study Riemann-Lebsgue theorem, Dini,s test, Dela vallee-Pouesin's test, summation of series by arithmetic means.
(ii)To understand summability of Fourier series, Weierstrass approximation heorem and related results.
(iii)To study Bessel's inequality, Riesz-Fischer theorem, properties of Fourier coefficients, Conto's lemma, Riemann's First and second theorem. 4. To study special methods of summation.

Unit-I
The Fourier series of a periodic function, Convergence problem, Dirichlet's integral, n^{th} partial sum of Fourier series and its conjugate series, Riemann-Lebesgue theorem.

Unit-II
Convergence tests, Dini's test, Jordan's test, de la Vallee-Poussin's test, relation between the tests of Dini' Jordan and de la Vallee-Poussinn tests.

Unit-III
A continuous function with a divergent Fourier series, order of partial sums, integration of Fourier series, an example of convergent trigonometric series which is not Fourier series, Parseval's theorem for continuous functions.

Unit-IV
Function of class L^2; Bessel's inequality, Parseval's theorem for functions of class L^2, the Riesz-Fischer theorem, properties of Fourier coefficients, uniqueness of trigonometric series, Cantor's lemma, Riemann's first and second theorems.

Recommended Books:
1. E.C. Titchmarsh: A Theory of Functions, Oxford University Press, 1939.
2. 2. A Zygmund: Trigonometric series Vol. I, The University Press, Cambridge 1959.
3. 3. G. H. Hardy: Divergent series, The Clarendon Press, Oxford, 1949.

Course Outcomes: After the course the students will be able to
CO 1. understand the basics of Fourier series and summability theory.

CO 2. to understand the use of this course in different field of mathematical Analysis.
CO 3. to think and develop new ideas in this field.

Paper	Course Code	Course Title	Total Credit
IV	MAT-532	Cosmology	4+0

Course Objectives: The main objectives are:
(i) Cosmology is a branch of science in which we study the evolution of universethrough a construct the cosmological models.
(ii) All of modern physics is based on the theory of relativity and quantum mechanics. To provide the students with sufficient exposure to general theory of relativity and gravitation that to understand the physical universe.
(iii) Improving the understanding of space time and physical phenomenon of the universe.
(iv) As part of the applications of general theory of relativity, the course will help for the mathematical modelling of the physical universe and discuss its properties.

Unit I

Static cosmological models, Einstein Universe, de-Sitter Universe, Hubble law, Weyl Postulate

Unit II

Non-Static cosmological models, Friedmann-Lemaitre-Robertson-Walker (FLRW) cosmological models and its properties, Cosmological models with a cosmological constant

Unit III

The Redshift, Observational parameters, Horizon and Hubble radius, Aungular size, Luminosity, Luminosity distance relationship, Angular size, Source Counts, Age of universe, The big bang theory.

Unit IV
Life Cycle of a Star, Gravitational Collapse, Gravitational Collapse of a Homogeneous Dust ball, Black Hole, The Kerr metric

Books Recommended:

1. K. D. Krori : Fundamentals of Special and General Relativity; PHI Publication, 2010.
2. S. R. Roy and Raj Bali : Theory of Relativity; Jaipur Publishing House, 2008.
3. Steven Weinberg : Gravitation and Cosmology : Principles and applications of General Relativity; Wiley Publ.,2005.
4. J. V. Narlikar : An Introductions to Relativity; Cambridge University Press, 2010.
5. I.B. Khriplovich : General Relativity; Springer Science + business media, 2005.

Course Outcomes: After completing the course, the student shall be able to
CO1. understand the basics of the physical universe.
CO2. understand the basics of cosmology and the basic tools for modelling the universe.
CO 3. provide the evolution of universe describe the origin, recent scenario and future of our universe.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-533**	**Wavelet Analysis**	**4+0**

Course Objectives: The objective of this paper is to study Fourier and inverse Fourier transforms convolution and delta function, Fourie transform of square integrable functions, wavelet transform, time frequency Analysis, Gabor transform, Dyadic wavelets and inversion, Wavelet series, Scaling functions and wavelets, Multi resolution analysis, orthogonal wavelets and wavelet Backet, Examples of orthogonal wavelets, orthogonal wavelet packets, orthogonal decomposition of wavelet series. The main objective of this paper is that to prepare the students for further research in wavelet analysis.

Unit I

Fourier Analysis: Fourier and inverse Fourier transforms, Convolution and delta function, Fourier transform of Square integrable functions. Fourier series,Poisson's Summation formula.

Unit II

Wavelet Transforms and Time Frequency Analysis: The Gabor Transform.Short-time Fourier transforms and the uncertainity principle. The integralwavelet transforms Dyadic wavelets and inversions.

Unit III

Frames. Wavelet Series. Scaling Functions and Wavelets: Multi resolution anal-ysis, scaling functions with _nite two scale relations. Direct sum decomposition of $L^2(R)$: Linear phase filtering.

Unit-IV

Compactly supported wavelets, Wavelets and their duals, Orthogonal Wavelets and Wavelet packets, Example of orthogonal Wavelets. Identi_cation of orthogonal two-scale symbols, Construction of Compactly supported orthogonal wavelets, Orthogonal wavelet packets, orthogonal decomposition of wavelet series.

Recommended Books:

1. C. K. Chui, A First Course in Wavelets, Academic press NY 1996.

2. Daubechies, Ten Lectures in Wavelets, Society for Industrial and Ap-plied Maths, 1992.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. understand the basics of this course.

CO 2. think and develop new ideas in this field.

CO 3. understand the use of this course in science and technology and other fields of Mathematical Analysis.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-534**	**Magneto Hydrodynamics**	**4+0**

Course Objectives: The objective of this course is to study Maxwell's equation, electromagnetic field in a conductor, rate of flow of charge, Alfven theorem, basic concept of viscid and Viscous magneto hydrodynamics Alfven wave, parallel study flow, Hartmann and Couette flow. Additional objective of the course is to prepare the students for research in applied mathematics.

Unit I

Maxwell equations, electromagnetic field in a conductor, MHD approximations, rate of flow of charge, important MHD parameters, diffusion of magnetic field, frozen-in-fields, integral of magnetic field equation, analogy of magnetic field with vorticity.

Unit II

Alfven theorem, Lorentz force and its transformations, Magnetic energy, Poynting vector theorems, basic equations of inviscid and viscous magnetohydrodynamics, energy conservation law.

Unit III

Alfven waves, MHD waves in a compressible fluid, Equipartition of energy of Alfven waves, MHD boundary conditions, equations of incompressible MHD flow.

Unit IV

Parallel steady flow, steady parallel flow in a conservative field of force, one-dimensional steady viscous MHD flow, Hartmann flow, Couette flow.

Books Recommended:

1. Alan Jeffery: Magnetohydrodynamics, Oliver and Boyd Ltd., Edinburgh,1966.
2. F. Chorlton: Text Book on Fluid Dynamics, C.B.S. Publishers, Delhi,1985.
3.S.I. Pai: Magnetohydrodynamics and Plasma Dynamics, Springer-Verlag,1962.
4. P. A. Davidson: Introduction to Magnetohydrodynamics, Cambridge University Press, U.K., 2017.

Course Outcomes: After the completion of the course, the students shall be able to

CO 1. understand the basic of Magnetohydrodynamics.

CO 2. know about Maxwell's equation, electromagnetic field, basic concepts of viscid and viscous MHD flow.

CO 3.do research in MHD.

Paper	Course Code	Course Title	Total Credit
IV	**MAT-535**	**Mathematics for Humanities**	**4+0**

Course Objectives: The main objective of this course is to make students aware of the fundamentals of Mathematics and to help them to explore applications of Mathematics in daily life.

Unit I

Functions and graphs, Elementary functions, Exponential functions and Natural Logarithms, Trigonometrical functions, Limit and continuity of Functions.

Unit II

The meaning of derivative, Calculus of derivative, Applications of derivative, Optimization, Exponential Growth and Decay, Linearization of Functions.

Unit III

Functions of two variables, Graphical representation of functions, Linearization of functions of two variables, Vectors and matrices, System of linear equations, The inverse matrix.

Unit IV

First order ordinary differential equations, Applications of ordinary differential equation in exponential growth and decay, Solutions and direction fields, Ordinary differential equation with variables separable. The spread of infectious diseases, Drug dosage.

Books Recommended:

1. Shaffer Hall**:** Differential and Integral calculus with Applications, MEDTECH, Scientific International Pvt. Ltd.
2. Arun Kumar: Mathematics for Biologists, Narosa Publishing House, New Delhi

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. understand basics of mathematics for humanities.

CO 2. apply mathematics as a tool to study real world problems and analyse them.

CO 3. do research in applied mathematics.

Paper	Course Code	Course Title	Total Credit
V	**MAT-536**	**Fixed Point Theory and its Applications**	**4+0**

Course Objectives: A fixed point theory is a collection of results saying that a function will have at least one fixed point under some conditions on function. Fixed point has been revealed as a very powerful and important tool in the study of nonlinear phenomena. The main objective of this paper is that to prepare the students for further research in fixed point theory.

Unit I

Back ground of Metrical fixed point theory, Fixed Points, Uniformly convex, strictly convex and reflexive Banach spaces, Lipschitzian and contraction mapping, Banach's contraction principle, Application to Volterra and Fredholm integral equations, Caristi's fixed point theorem.

Unit II

Nonexpansive, asymptotically nonexpansive and quasi-nonexpansive mappings and Fixed Points, Fixed point theorems for nonexpansive mappings, Nonexpansive operators in Banach spaces satisfying Opial's conditions, The demiclosedness principle.

Unit III

Brouwer's fixed point theorem, Schauder's fixed point theorem, Measure of Non- Compactness, Condensing map, Fixed points for condensing maps, Strict convexity, Uniform convexity, The modulus of convexity and normal structure, Smoothness, retraction map, Sadovskii's fixed point theorem, Introduction of Set-valued mappings, Set-valued contraction map, Housdroff metric, Nadler's fixed point theorem.

Unit IV

Fixed point iteration procedures: Krasnoselskii's iteration, Picard's iteration, The Mann Iteration, Lipschitzian and Pseudocontractive operators in Hilbert spaces, Strongly pseudocontractive operators in Banach spaces, The Ishikawa iteration, Equivalence between Mann and Ishikawa iterations, S-iteration, Hybrid iteration.

Books Recommended:

1 V. Berinde, Iterative Approximation of Fixed Points, Lecture Notes in Mathematics, No. 1912, Springer, 2007.

2 M. A. Khamsi and W. A. Kirk, An Introduction to Metric Spaces and Fixed Point Theory, John Wiley & Sons, New York, 2001.

3 Sankatha P. Singh, B. Watson and P. Srivastava, Fixed Point Theory and Best Approximation:The KKM-map Principle, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1997.

4 V. I. Istratescu, Fixed Point Theory, An Introduction, D. Reidel Publishing Co., 1981. 5. K.Goebel and W. A. Kirk, Topic in Metric Fixed Point Theory, Cambridge University Press, 1990.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. apply fixed point theory and its applications in finding unique solution of differential and integral equations.

CO 2. understand its applications in biology, chemistry, economics, game theory, engineering physics.

CO 3. entre into wide area of research in analysis.

Paper	Course Code	Course Title	Total Credit
V	MAT-537	Bio Mathematics	4+0

Course Objectives: The objective of this paper is to study the application of bio mathematics in the analysis of biological systems and to show how mathematics and computing can be used in an integrated way to analyze biological systems. The main objective of this paper is to prepare the students for further research in Bio Mathematics.

Unit I

Introduction of Biomathematics, role and scope of Mathematics in Biosciences, Bio-fluid dynamics, external and internal Bio-fluid dynamics, fluid continuum, viscosity and kinematic viscosity, Newtonian and Non-Newtonian fluids, basic equations used in Bio- fluid dynamics, Poiseuille's law, Reynold's number and its importance in biological flow.

Unit II

Human cardiovascular system, composition of blood, characteristics of blood flow, blood flow through artery with mild stenosis, two layered flows in a tube with mild stenosis, pulsatile flow of blood in rigid tube.

Unit III

Human respiratory system, gas exchange and air flow in human lungs, consumption and transport of oxygen in human lungs, Weibel's model for flows in human lung airways, comparison between flows of blood and flows in lung airways.

Unit IV

Introduction and process of diffusion, Fick's laws of diffusion, Diffusion equation and its solution, modifications of diffusion equation, diffusion through a membrane, convective transport, diffusion in artificial kidney.

Books Recommended:

1. J.N. Kapur: Mathematical Models in Biology and Medicine, Affiliated East-West Press Pvt. Ltd., New Delhi, 1985.

2. J. Mazumdar: An Introduction to Mathematical Physiology and Biology, Cambridge University Press, 1999.

3. Y.C. Fung: Bio-Mechanics, Springer-Verlag New York Inc., 1990.

Course outcomes: After the completion of the course, the student shall be able to

CO 1. have an enhanced knowledge and understanding of mathematical modelling and analysis of biological systems.

CO 2. have sound knowledge of developing mathematical models in the areas of Bio sciences and bio fluid dynamics.

CO 3. predict the behavior of biological systems using mathematical modelling.

Paper	Course Code	Course Title	Total Credit
V	MAT-538	Contact Manifolds	4+0

Course Objectives: The paper of Contact Manifolds is introduced to M.Sc. classes for the study of AlmostContact Manifolds, Normal contact structure, Affinily almost cosymplectic manifold, Almost Grayan Manifolds, Sasakian Manifolds, Properties of projective, conformal curvatures in Sasakian manifold, Concircular and con- harmonic curvatures in Sasakian manifold. Cosymplectic structure and Nearly Cosymplectic structure. The main objective of Contact Manifolds is that to prepare the students for further research in analysis of differential geometry, structure of differentiable manifold and analysis.

Unit I

Almost Contact Manifolds: Definition. Eigen values of F. Intergrability conditions of π_m, π_m and π_1. Lie derivative. Normal contact structure. Affinily almost cosymplectic manifold.

Unit II

Almost Grayan Manifolds: Introduction. D-conformal transformation. Particular affine connections. Almost Sasakian manifold. Quasi-Sasakian manifold.

Unit III

Sasakian Manifolds: K-contact Riemannian manifold and its properties, Sasakian manifold and its properties. Properties of Projective curvature tensor in Sasakian manifold.

Unit IV

Conformal, Concircular and Con- harmonic curvature tensor in Sasakian manifold. Cosymplectic structure and Nearly Cosymplectic structure.

Books Recommended:

1. R.S. Mishra: Structure on differentiable manifold and their application, Chandrama Prakashan, Allahabad, 1984.

2. K. Yano and M. Kon: Structures of Manifolds, World Scientific Publishing Co. Pvt. Ltd.,1984.

3. U.C. De and A.A.Shaaikh, Complex and Contact Manifolds, Narosa Publishing House, New Delhi 2009.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. investigate basic structure of differentiable manifold.

CO2. demonstrate an intuitive and computational understanding of Differentiable manifold, Riemannian Manifold, Almost Contact Manifolds, Normal contact structure, Affinily almost cosymplectic manifold, Almost Grayan Manifolds, Sasakian Manifolds, Properties of projective, conformal curvatures in Sasakian manifold, Concircular and con- harmonic curvatures in Sasakian manifold. Cosymplectic structure and Nearly Cosymplectic structure.

CO3. do research in differential geometry and analysis of differential geometry.

Paper	Course Code	Course Title	Total Credit
V	MAT-539	Finsler Geometry	4+0

Course Objectives: The objective of this paper is to study Finsler metric function, Dual tangent space, Geodesics, Fundamental postulates of Cartan, Berwald's covariant derivative and its properties, Commutation formula resulting from partial δ-differentiation, Three curvature tensors of Cartan.The main objective of this paper is that to prepare the students for further research in differential geometry and Finsler Geometry.

Unit I

Finsler metric function. Its properties. Tangent space. Indicatrix. Metric tensor and C-tensor Homogeneity properties of gij and Cijk .

Unit II

Dual tangent space. Geodesics. δ-differentiation.Partial δ-differentiation. Properties of partial δ-differentiation.

Unit III

Fundamental postulates of Cartan. Cartan's covariant derivatives and their properties.Geometry of paths. Berwald's covariant derivative and its properties.

Unit IV

Commutation formula resulting from partial δ-differentiation. Other commutation formulae. Three curvature tensors of Cartan. Identities satisfied by curvature tensors including Bianchi identities.

Books Recommended:

1. H. Rund: The Differential Geometry of Finsler Spaces, Springer-Verlag, 1959.

2. M. Matsumoto: Foundations of Finsler Geometry and special Finsler spaces, Kaiseisha Press, Saikawa, Otsu, 520 Japan, 1986.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. understand the basic of this course and think & develop new ideas in this course.
CO 2. know Finsler metric function, Dual tangent space, Geodesics, Fundamental postulates of Cartan, Berwald's covariant derivative and its properties, Commutation formula resulting from partial δ-differentiation, Three curvature tensors of Cartan.
CO 3. do research in differential geometry & Finsler Geometry.

Paper	Course Code	Course Title	Total Credit
V	MAT-540	Mathematics for Life Sciences	4+0

Course Objectives: The objective of this paper is to study the simple epidemic and SIS diseases, SIR epidemics, SIR endemics, Modelling AIDS epidemic, Tumor modelling, Phenomenological models, Human genetics, Basic models for inheritance, Genetic matrices, Hardy-Weinberg law, Models for Genetic Improvement.

Unit I

The simple epidemic and SIS diseases, SIR epidemics, SIR endemics: No desease related death including disease related death, eradication and control, Vector-borne diseases, Basic model for macro parasitic diseases.

Unit II

Modelling AIDS epidemic, Anderson's first model, Anderson's improved model, Interaction of HIV and Immune system, Stages in the course of HIV infection, Treatment of HIV infection, Modelling of HIV immunology, Analysis of treatment of HIV infection.

Unit III

Tumor modelling, Phenomenological models, Nutrients, Diffusion limited stages, Moving boundary problem, Growth promotors and inhibitors, Vascularizations, Metastasis, Immune system response.

Unit IV

Human genetics, Basic models for inheritance, Genetic matrices, Hardy-Weinberg law, Correlation between Genetic composition of siblings, Phenotype ratios, Multiple alleles and Application to Blood Group, Inheritance of sex linked characterestics, Models for Genetic Improvement: Selection and Mutation.

Books Recommended:

1. J. Mazumdar: An Introduction to Mathematical Physiology and Biology, Combridge University Press.

2. Nicholas F. Britton: Essential Mathematical Biology, Springer

3. J. N. Kapur: Mathematical Models in Biology and Medicine, Affiliated East-west Press Pvt. Ltd., New Delhi.

4. Fred Brauer, Carlos Castillo-Chavez: Mathematical Models in Population Biology and Epidemiology, Springer

5. Matt J. Keeling and Pejman Rohani: Modelling Infeccious Diseases in Humans and Animals, Princton University Press.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1. understand the basic of this course and think & develop new ideas in this course.

CO 2. know the simple epidemic and SIS diseases, SIR epidemics, SIR endemics, Modelling AIDS epidemic, Tumor modelling, Phenomenological models, Human genetics, Basic models for inheritance, Genetic matrices, Hardy-Weinberg law, Models for Genetic Improvement.

CO 3. do research in applied mathematics and bio—mathematics.

Paper	Course Code	Paper Title	Total Credit
VI	**MAT-541**	**Dissertation/Survey** (the marks of dissertation/survey based on internal evaluation)	**0+4**

Course Objectives: The objective of course is to write a dissertation/survey on the specific topic typed in LaTex.

Candidate/Students should write a dissertation/survey on the specific topic based on any one core/major papers or discipline specific elective/elective papers opted by the student in Semester-I or II or III or IV. The students has been allotted a supervisor in this project on their topic, given by the concern faculty of the core or elective papers. The dissertation/survey should be typed in LaTex and its presentation on LaTex Beamer/Power Point. **(04-Credits)**

Course Outcomes: After completing the course, the student shall be able to
CO 1. understand the basics to write a dissertation/survey on the specific topic.
CO 2. understand some advanced computing tools.
CO 3. understand some advanced research techniques.