Mahatma Jyotiba Phule Rohilkhand University, Bareilly

(A State University)

NEW REVISED SYLLABUS FOR POST-GRADUATION IN MATHEMATICS ACCORDING TO THE NEP PG ORDINANCE

M. J. P. ROHILKHAND UNIVERSITY, BAREILLY

TO BE IMPLEMENTED WITH EFFECT

FROM THE ACADEMIC YEAR 2022 - 2023

Mission

• To contribute towards building calibre of the students by providing quality education and research in Mathematics through updated curriculum, effective teaching learning process.

• To impart innovative skills, team-work, ethical practices to the students so as to meet societal expectations.

• To build a strong base in Mathematics for various academic programs across the institute.

About the Mathematics

Mathematics is a powerful tool for global understanding and communication that organizes our lives and prevents chaos. Mathematics helps us understand the world and provides an effective way of building mental discipline. Mathematics encourages logical reasoning, critical thinking, creative thinking, abstract or spatial thinking, problem-solving ability, and even effective communication skills. Mathematics is necessary to understand the other branches of knowledge. All depend on mathematics in one way or another. There is no science, art, or specialty except mathematics was the key to it. The discipline and mastery of any other science or art are very much related to the size of mathematics.

Duration:

M.Sc./M.A. Mathematics is a full-time postgraduate level program offered by the Department of Mathematics. This is a 2-years program, consisting of four semesters with two semesters per year.

Eligibility:

For M.Sc. in Mathematics, the candidates with the following qualification are eligible: B.Sc./B.A. (Hons.) in Mathematics from any recognized Indian or foreign university OR B.Sc./B.A. with Mathematics as one of the major subject of study.

Program Educational Objectives (PEOs)

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

Program Outcome:

Graduate will be able to

a) Progress the critical analysis and problem solving skills required for research and development organization and industry.
b) Communicate confidently and effectively with industry and society at large, regarding complex problem and solution of the problem, existing around.

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

The board of studies for Master of Science in Mathematics of department of mathematics includes the following members:

1. Dr N. K. Sharma, Associate Prof., Dept. of Maths., SM College, Chandausi, Convener
2. Prof. Sanjeev Rajan, Dept. of Maths., Hindu College, Moradabad, Member
3. Dr Arif Nadeem, Associate Prof., Dept. of Maths., Bareilly College, Bareilly, Member
4. Prof. T.S. Chauhan, Dept. of Maths., Bareilly College, Bareilly, Member
5. Dr Harish Chandra Srivastva, Associate Prof., Dept. of Maths., SS College, Shahjahanpur,Member
6. Dr Abdul Salam, Associate Prof., Dept. of Maths., GF College, Shahjahanpur, Member
7. Prof. M.C. Joshi, Kumayun University, Nainital
8. Prof. Sanjay Chadhary, B.R. Ambedkar Univeersity, Agra

Qualification Descriptors (possible career pathways)

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

1. Teaching

2. Research

3. Engineering

4. Computer programming (In different MNC's)

5. Statistician

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

7. Can go for UPSC/Civil services exam.

8. Finance

9. Science and business

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SEMESTER-WISE COURSES AND CREDIT DISTRIBUTION

SEMESTER-I

Core Course (CC), Discipline Centric Elective Courses (DCEC), Minor Elective Course (MEC)

Total Credits: 26 (CC: 22, MEC: 4)

Sr. No.	Course Code	Course name	Total Credits
1	MATHCC0411	Advanced Algebra	4
2	MATHCC0412	Real Analysis	4
3	MATHCC0413	Differential Equation with applications	4
4	MATHCC0414	Fluid Dynamics	4
5	MATHCC0415	Power point presentation and viva-voce	6
		Minor Elective Course	
6	MATHMEC0416	MOOC/MEC	4

Minor Elective Courses for M.Sc. (Mathematics)
(Students will choose any one paper.)

Course Code	Course name	Total Credits
MATHMEC0416A	Theory of Differential Equation	4
MATHMEC0416B	Information Theory-I	4

Note: 1. One project/Dissertation/Survey/Industrial training should be allotted to each student in the second week of first semester in the supervision of faculty members of the department and the complete project should be submitted at end of the second semester.

2. If any student published any research paper in UGC Care listed journal during PG programme from this project report, he will be given 25% extra marks which he has been awarded out of 100 marks. Maximum obtained marks will be 100 only.

For example,

(i) if a student obtains 75 marks in project and he has published a research paper during his project work then his final marks will be

$$75 + 25\%\ of\ 75 = 75 + 18.75 = 93.75 = 94$$

(ii) if a student obtains 88 marks in project and he has published a research paper during his project work then his final marks will be

$$88 + 25\%\ of\ 88 = 88 + 22 = 110$$

But he will be awarded only 100 marks.

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SEMESTER-II

Total Credits: 26 (CC: 14, DCEC: 08, MEC: 04)

Sr. No.	Course Code	Course name	Total Credits
7	MATHCC0421	Advanced Complex Analysis	4
8	MATHCC0422	Topology	4
9	MATHCC0423	Project/ Dissertation /Survey/Industrial training and viva-voce	6
		Discipline Centric Elective Courses	
10	MATHDCEC0424	MOOC/DCEC	4
11	MATHDCEC0425	MOOC/DCEC	4

Discipline Centric Elective Courses for M.Sc. (Mathematics)

(Students will choose any two papers)

Course Code	Course name	Total Credits
MATHDCEC0424&425A	Advanced Discrete Mathematics	4
MATHDCEC0424&425B	Differential Geometry	4
MATHDCEC0424&425C	Advanced Abstract Algebra	4

		Minor Elective Course	
12	MATHMEC0426	MOOC/MEC	4

Minor Elective Courses for M.Sc. (Mathematics)

(Students will choose any one paper.)

Course Code	Course name	Total Credits
MATHMEC0426A	Mathematical Modelling	4
MATHMEC0426B	Number Theory	4

SEMESTER-III

Total Credits: 26 (CC: 18, DCEC: 4, MEC: 4)

Sr. No.	Course Code	Course name	Tota Credits
13	MATHCC0431	Partial Differential Equation with Applications	4
14	MATHCC0432	Operation Research	4
15	MATHCC0433	Functional Analysis	4
16	MATHCC0434	Seminar Presentation and Viva-Voce	6
		Discipline Centric Elective Courses	
17	MATHDCEC0435	MOOC/DCEC	4

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Discipline Centric Elective Courses for M.Sc. (Mathematics)

(Students will choose any one paper)

Course Code	Course name	Total Credits
MATHDCEC0435A	Difference Equations	4
MATHDCEC0435B	Fuzzy set Theory	4

Minor Elective Course

18	MATHMEC0436	MOOC/MEC	4

Minor Elective Courses for M.Sc. (Mathematics)

(Students will choose any one paper.)

Course Code	Course name	Total Credits
MATHMEC0436A	Measure Theory and Integration	4
MATHMEC0436B	Introduction to Cryptography	4

Note-1: One project/Dissertation/Survey/Industrial Training should be allotted to each student in the second week of third semester in the supervision of faculty members of the department and the complete project should be submitted at endof the fourth semester.

2. If any student published any research paper in UGC Care listed journal during PG Programme from this project report, he will be given 25% extra marks which he has been awarded out of 100 marks. Maximum obtained marks will be 100 only.

For example,

(i) if a student obtain 75 marks in project and he has published a research paper during his project work then his final marks will be

$$75 + 25\%\ of\ 75 = 75 + 18.75 = 93.75 = 94$$

(ii) if a student obtain 88 marks in project and he has published a research paper during his project work then his final marks will be

$$88 + 25\%\ of\ 88 = 88 + 22 = 110$$

But he will be awarded only 100 marks.

SEMESTER-IV

Total Credits: 26 (CC: 14, DCEC: 8, MEC: 4)

Sr. No.	Course Code	Course name	Total Credits
19	MATHCC0441	Mathematical Statistics	4
20	MATHCC0442	Advanced Fluid Dynamics	4
21	MATHCC0443	Project/Dissertation and viva-voce	6
	Discipline Centric Elective Courses		
22	MATHDCEC0444	MOOC/DCEC	4
23	MATHDCEC0445	MOOC/DCEC	4

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Discipline Centric Elective Courses for M.Sc. (Mathematics)

(Students will choose any two papers)

Course Code	Course name	Total Credits
MATHDCEC0444&445A	Integral Equation	4
MATHDCEC0444&445B	Theory of Elasticity	4
MATHDCEC0444&445C	Tensors and General Relativity	4
MATHDCEC0444&445D	Information Theory-II	4
MATHDCEC0444&445E	Bio-Mathematics	4
MATHDCEC0444&445F	Mathematics for Finance and Insurance	4
MATHDCEC0444&445G	Wavelet Analysis	4
MATHDCEC0444&445H	Differential Geometry of Manifolds	4

Minor Elective Course

24	MATHMEC0446	MOOC/MEC	4

Minor Elective Courses for M.Sc. (Mathematics)

Course Code	Course name	Total Credits
MATHMEC0446	Student has to take one minor elective course from any other stream/subject/ department.	4

Note: The Programme of Post-Graduation in Mathematics will be two years duration. Each year is divided into two Semesters of equal durations. The Programme requires students to take a combination of Core Courses (Major), Discipline Centric Elective Courses, Electives (Minor) and Industrial Training/Survey/Research Project/Dissertation. A studentis required to complete a minimum of 104 Credits (52 Credits in 1st year and 52 Credits in 2nd year) for thecompletion of the Programme and the award of the Master of Science in Mathematics degree. The entire Programme is based on CBCS system. In brief, the entire Programme of Post-Graduation in Mathematics has been organized into Four Semesters.

Criteria for Internal Class Evaluation for all 4 semester papers:

Class Test + Presentations/Assignments = 20 +10 = 30 marks

Guidelines for Industrial Training/ Project/Survey/Dissertation

In each year of the Programme of Post-Graduation in Mathematics (i.e., during both the Semesters) students will have to opt either Industrial Training/ Project/Survey/Dissertation. It will carry 6 Credits in Second Semester. The purpose of undertaking a project is to conduct a systematic study related to his/her opted papers. The entire project will be guided by a Faculty Member as well as by a Firm's Official. Students are advised to work in areas that would be of importance to the business organisation and provide policy recommendations for improvement. They will submit a Progress Report at the end of 1st Semester and 3rd Semester and a Detailed Final Report at the end of1st year (2nd Semester) and 2nd year (4th Semester). This Detailed Final Report will be evaluated through a Viva – Voce,jointly by the Supervisor and the External

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Examiner. As regards the option for Dissertation, through this, students will undertake a research work based on the area of his/her research interest. The Dissertation work will be carried out under the guidance and supervision of a Faculty Member. At the end of the year, students will submit a complied Project Report/Dissertation and it will be evaluated through the Viva – Voce, jointly by the Supervisorand the External Examiner.

Course Curriculum

Ist Semester

Course Code	**MATHCC0411**	**Course Name**	**Advanced Algebra**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	This course introduces the basic concepts of modern algebra such as groups and rings. The philosophy of this course is that modern algebraic notions play a fundamental role in mathematics itself and in applications to areas such as physics, computer science, economics and engineering.		

Course Outcomes:	After completing this course, student is expected to learn the following: 1: Explain the fundamental concepts of advanced algebra such as groups and rings and their role in modern mathematics and applied contexts. 2: Demonstrate accurate and efficient use of advanced algebraic techniques. 3: Demonstrate capacity for mathematical reasoning through analysing, proving and explaining concepts from advanced algebra. 4: Apply problem-solving using advanced algebraic techniques applied to diverse situations in physics, engineering and other mathematical contexts.

COURSE SYLLABUS

Units	Content of Each unit
1	Review of basic Group Theory, Cauchy's theorem, Sylow theorems, Direct product of groups, Normal and Subnormal Series, Compostion Series, Jordan-Holder theorem, Solvable groups, Nilpotent groups.
2	Review of basic Ring Theory, Ring homomorphism, Ideals and Factor rings, Prime and Maximal ideals, Euclidean domains, Principal ideal domains and unique factorization domains, Polynomial rings,Factorization of Polynomials.
3	Extension fields, Splitting fields, Algebraic and Transcendental extensions, Simple extensions, Separable extensions, Finite fields. Galois Theory, Fundamental Theorem of Galois Theory, Solvability of Polynomials by Radicals.
4	Modules, Submodules, Quotient modules, Homomorphism and Isomorphism theorem, Nilpotent transformations, Jordan blocks and Jordan forms, Inner product space, Triangle inequality, Schwarz's Inequality, Bessel's Inequality.

Suggested Readings:

1. Gallian, J. A. Contemporary Abstract Algebra. 9th edition. Cengage Learning, 2015.
2. Lang, S. Algebra. 3rd edition, Springer 2012.
3. Herstein, I. N. Topics in Algebra. 2ndedition. John Wiley and Sons, 2006.
4. Bhattacharya, P. B. Jain, S. K. and Nagpaul, S. R. Basic Abstract Algebra. 2 nd edition, Cambridge University Press, 2003.
5. Khanna, V. K. and Bhammbri, S. K. A Course in Abstract Algebra. Vikas Publishing house, 1999.
6. Cohn, P. M. Algebra. Vols. I & II, John Wiley & Sons, 1991.
7. Luther, S. and Passi, I. B. S. Algebra. Vol. I-Groups, Vol. II-Rings, Narosa Publishing House (Vol. I – 1996, Vol. II –1990).
8. Axler, S.: Linear Algebra Done Right, 2nd edn. Undergraduate Texts in Mathematics. Springer, New York (1997)
9. Brian C. Hall, Lie Groups, Lie Algebras, and Representations: An Elementary Introduction, GTM Springer, 2015

Course Code	**MATHCC0412**	**Course Name**	**Real Analysis**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL

Course Objective	The course will develop a deep and rigorous understanding of real line ℝ and of defining terms to prove the results about convergence and divergence of sequences and series of real numbers. The course will also develop the understanding of metric spaces and convergence, compactness, sequential compactness and connectedness in metric spaces. These concepts have wide range of applications in real life scenario.
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand many properties of the real line and learn to define sequence in terms of functions from ℕ to a subset of ℝ. 2: Recognize bounded, convergent, divergent, Cauchy and monotonic sequences. To calculate the limit superior, limit inferior of sequences and limit of a bounded sequence, Riemann integration theory. 3: Recognize Riemann-Stieltjes integral and integration of vector valued function. 4: Recognize bounded variation, total variation, directional derivatives, partial derivative and derivative as a linear transformation.

COURSE SYLLABUS

Units	Content of Each unit
1	Sequences and series of real valued functions, pointwise convergence, uniform convergence, Cauchy's criterion and test for uniform convergence of sequence of functions. Tests for uniform convergence of series of functions (Weierstrass's M-test, Abel's test, Dirichlet's test). Uniform convergence and continuity, Dini's theorem, The Weierstrass approximation theorem.
2	Convergence of Sequences of Measurable Functions: Convergence in Measure, Uniform Convergence, Theorems on Convergence of Sequences of Measurable Functions, Lebesgue Convergence Theorem, Dominated Convergence Theorem, Beppo Levi's Theorem, Fatou's Lemma, Lebesgue Differentiation Theorem, Riemann integration of real valued functions, Existence of the integral, integral as a limit of a sum, first mean value theorem, Second mean value theorem.
3	Definition and existence of Riemann-Stieltjes integral, Properties of integrals, integration and differentiation, Fundamental theorem of calculus.
4	Function of bounded variation, function of bounded variations expressedas difference of increasing functions, function of several variables, partial differentiation, partial derivative of functions of two variable, Integral as a function of parameter, inverse and implicit function theorems, Chain rule, Jacobian, Taylor's theorem for two variables, Tauber's theorem.

Suggested Readings:

1. Walter, R. Principles of Mathematical Analysis. 3rdedition, McGraw-Hill, 2017.
2. Simmons, G. F. Introduction to Topology and Modern Analysis. McGraw-Hill Pvt. Ltd. 2016.
3. Kumaresan, S. Topology of Metric Spaces. Narosa Publishing House, 2011.
4. Terence T. Analysis II. Hindustan Book Agency, 2009.
5. Malik, S. C. and Arora, S. Mathematical Analysis. 2nd edition reprint. New Age International Publishers 2005.
6. Apostol, T. M. Mathematical Analysis. 2 nd edition. Wesley Publishing Co. 2002.
7. Somasundram, D. and Chaudhary, B. A First Course in Mathematical Analysis. Narosa Publishing House, 1996.
8. Royden, H. L. Real Analysis, Macmillan Pub. Co., Inc. 4th edition, New York, 1993.

Course Code	MATHCC0413	Course Name	Differential Equation with applications
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of Course	NIL
Course Objective	The objective of this course is to introduce the theory of ordinary differential equations, fundamental theorems for existence and uniqueness differential equations (DE's).		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the stability and Poincare Bendixson theory of ordinary differential equations. 2: Understand the behaviour of solutions of differential equations. 3: Understand the Strum theory for second order ODEs. 4. Understand the construction of Greens functions and their applications to solve ODEs.		

COURSE SYLLABUS

Units	Content of Each unit
1	Lipschitz Condition, Equi-continuity, System of Differential Equations, m^{th} Order Differential Equation in n- dimensions, Concept of Existence, Ascoli-Aerzela Theorem, A theorem of convergence of solutions of a family of initial value problems, Picard's Successive Approximation method, Picard's Theorem, Picard's Second Theorem, Picard-Lindelof Theorem, Existence and uniqueness theory, Cauchy Pearo's Theorem, Continuation of Solutions, BanachFixed Point Theorem, Wroskian.
2	Differential inequalities, One Sided Lipschitz Condition, Maximal and Minimal Solutions, Differential and Integral Inequalities, The Gronwall's Inequality, Theorem of Wintner, Kamke's Uniqueness Theorem, Nagumo's Criteria, Osgood's Criteria, Successive Approximations.
3	Stability and Poincare Bendixon theory, Phase Plane, Critical Points,Isolated Critical Points, Some Special Critical Points, Centre, Saddle Point, Spiral or FocalPoint, Node, Liapunov Function, Liapunov Stability Theorem, Liapunov Asymptotic Stability Condition, Liapunov Instability Theorem, Non–Linear System, Bendixon Theorem, Poincare – Bendixon Theorem.
4	Strum theory in linear second order ODEs, Adjoint Differential Equation, Abel-Liouville Formula, Fundamental matrix, Adjoint System, Solution of Nonhomogeneous Differential Equation, Floquet Theory, Matrix method for solution of linear differential equations with constant coefficients, Abel's Formula, Strum Separation Theorem, Strum Comparison Theorem, Existence and uniqueness Theorem, Orthogonal and Orthonormal Functions, Strum-Liouville's Problems, Eigen Values and Eigen Functions, Strum – Liouville's Theorem, Eigen Values of Strum – Liouville's Problem.

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

Course code	**MATHCC0414**	**Course Name**	**Fluid Dynamics**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to provide a treatment of topics in fluid dynamics to a standard where the student will be able to apply the techniques used in deriving a range of important results and in research problems. The objective is to provide the student with knowledge of the fundamentals of fluid dynamics and an appreciation of their application to real world problems.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the basic principles of fluid dynamics, such as Lagrangian and Eulerian approach etc. 2: Use the concept of stress in fluids with applications. 3: Analyse Irrotational and rotational flows in fluids and some of their properties 4: Find analytical solution of Navier Stoke equation and solutions of some benchmark problems		

COURSE SYLLABUS

Units	Content of Each unit
1	Kinematics - Lagrangian and Eulerian methods. Equation of continuity. Boundary surfaces. Stream lines, Path lines and stream lines. Velocity potential. Irrotational and rotational motions. Vortex lines.
2	Equations of motion – Lagrange's and Euler's equations of motion, Conservative field of force, Bernoulli's Theorem, Equation of motion by flux method, Impulsive actions, Circulation, Kelvin's circulation theorem, Minimum energy theorem.
3	Motion in two dimensions: Stream function, Irrotational motion in two-dimensions. Complex velocity potential, sources, sinks, doublets and images, Milne-Thomson circle Theorem, Theorem of Blasius.
4	Motion of Cylinder: Motion of a circular cylinder, Liquid streaming past a fixed circular cylinder, Motion of two co-axial cylinders, Elliptic cylinder moves in an infinite liquid, Liquid streaming past a fixed elliptic cylinder, Circulation about an elliptic cylinder, Kutta-Joukowski theorem,

Suggested Readings:

1. Besaint, W.H. and Ramsey, A.S. A Treatise on Hydromechanics Part Ihydrost itics, Andesite Press, 2017.
2. Kundu, P.K., Cohen, I. M. and Dowling, R. D. Fluid Mechanics, 6th edition, Academic Press, 2015.
3. O'Neil, M. E., and Chorlton, F. Ideal and Incompressible Fluid Dynamics. Ellis Horwood Ltd, 1986.
4. Yuan, S.W. Foundations of Fluid Mechanics. Prentice Hall of India Private Limited, New Delhi, 1976.
5. Curle, N. and Davies, H. J. Modern Fluid Dynamics.Vol1, D Van Nostrand Company Ltd, London, 1968.

Course code	**MATHCC0415**	**Course Name**	**Power point presentation and viva-voce**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, PPT and Viva-voce -70 marks)		
Course Objective	The purpose of this course is to enhance communication skills and presentation. How to face interviews in competitions.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Will be able to present the subject in interviews. 2: Get ability to face interviews. 3: Skills to write subject in own way. 4: Get knowledge of preparing Dissertation, Thesis and Books.		

Pattern

1	Viva-voce and Presentation of assigned / selected problem /topic using PPT by each student ineach of the other four papers to be evaluated in the presence of one internal and one external examiner.

MOOC/MEC courses offered to M.Sc. (Mathematics) students:

Course code	MATHMEC0416A	Course Name	Theory of differential Equations
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL

Course Objectice- The Objective of this course is to introduce the theory of ordinary differential equations, fundamental theorems for existence and uniqueness differential equations (DE's)

Unit:-

I. Existence and uniqueness Theorem of Homogeneous and NonHomogeneous equations with constant coefficients. Theory ofequations with variable coefficients. Method of variation of parameters and the formula for particular integral in terms of Wronskian.

II. Series solution of second order linear differential equations nearordinary_point. Singularity and the solution in the neighborhoodof regular singular point. Euler equation and Frobenius method.

III. Solutions of Hypermite and Laguerre differential equations.

IV. Solutions of Recti's equations.

REFERENCES

1. Earl A. Codington, An Introduction to Ordinary Differentia Equations.
2. Elementary Differential Equations and Boundary valueproblems.
3. D.A. Murray, Introductory Course on Differential Equations.Orient Longman (India),1967.
4. A.R. Forsyth. A Trestise on Differential Equations, Macmillan &Co. Ltd., London.
5. Differential equation with Applications and Historical notes: G.F.Simmons, CRC Press, Taylor & Francis Group.
6. Advanced Differential Equations: M.D. Raisinghania, S. ChandPvt. Ltd., 2008,

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Course code	MATHDCEC0416B	Course Name	Information Theory-I
Programme	M.A./M.Sc. Mathematics	Credits	4
Hrs/Weeks	-	Total Hours	60
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to introduce basic and advanced topics in information theory. This course further explains the different types of entropies, codes, discrete and continuous channels and their applications.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the basic concepts of information theory, different types of entropies withtheir properties and applications. 2: Analyse how different coding techniques will perform in different situations.3: Understand about discrete channels and their properties with applications.		
	4: Understand about continuous channels and their properties with applications.		

COURSE SYLLABUS

Units	Content of Each unit
1	Measure of information – axioms for a measure of uncertainty, the Shannon entropy and its properties. joint and conditional entropies, transformation and its properties, axiomatic characterization of the Shannon entropy due to Shannon and Fadeev.
2	Noiseless coding - ingredients of noiseless coding problem, uniquely decipherable codes, necessary and sufficient condition for the existence of instantaneous codes, construction of optimal codes.
3	Discrete memory less channel - classification of channels, information processed by a channel, calculation of channel capacity, decoding schemes the ideal observer, the fundamental theorem of information theory and its strong and weak converses.
4	Continuous channels - the time-discrete Gaussian channel, uncertainty of an absolutely continuous random variable, the converse to the coding theorem for time-discrete Gaussian channel, the time-continuous Gaussian channel, bandlimited channels.

Suggested Readings:

1. Ash, R. B. Information Theory. Courier Corporation, 2012.
2. Reza, F.M. An Introduction to Information Theory. Courier Corporation, 2012.
3. Hankerson, H. D., Harris, G. A. and Johnson, P. D. Introduction to Information Theory and Data Compression. Chapman and Hall/CRC, 2nd edition, 2003.
4. Aczel, J. and Daroczy, Z. On Measures of Information and their Characterizations. Academic Press, New York, 1975.

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SEMESTER-II CC Course

Course Code	MATHCC0421	Course Name	Advanced Complex Analysis
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The primary objective of this course is to understand the notion of logarithmically convex function and its fusion with maximum modulus theorem, the spaces of continuous, analytic and meromorphic functions, Runge's theorem and topics related with it, introduce harmonic function theory leading to Dirichlet's problem, theory of range of an entire function leading to Picard and related theorems.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the basics of logarithmically convex function that helps in extending maximum modulus theorem. 2: Be familiar with metric on spaces of analytic, meromorphic and analytic functions, equi-continuity and normal families leading to Arzela-Ascoli and related theorems. 3: Appreciate the richness of simply connected region which connects various fields topology, analysis and algebra. 4: Know how big the range of an entire function is as well as Picard and related theorems.		

COURSE SYLLABUS

Units	Content of Each unit
1	Maximum modulus principle, Minimum modulus principle, Schwarz's lemma, convex functions and Hadamard's threecircles theorem, Three circles theorem as a convexity theorem, Phragmen-Lindelof theorem, Taylor theorem, Laurentz theorem, Fundamental theorm of algebra, Argument principle.
2	The space of continuous functions, spaces of analytic functions, Weierstrass factorization theorem. Gamma function, Reimann zeta function, Residue, Residue theorem, Steadily increasing function, Jordan's Lemma, Integration round unit circle, Evaluation of integrals when f(z) has no pole on real axis and poles on real axis, Rectangular contours.
3	Analytic continuation, Runge's theorem, Integral Function, Order of an Integral function, Canonical Product, Vitali's Convergence Theorem, Carleman's Theorem, Weierstrass's Theorem, Mittag-Leffier's theorem,Schwarz reflection principle. Hadamard's factorization theorem.
4	Basic properties of harmonic functions, Jensen's formula, Jensen's inequality, Jensen's theorem, Poisson-Jensen Formula, Picard theorem, Schottky's theorem, Infinite Product, General principle of convergence of Infinite product, Absolutely Convergence, Derangement of Factors, Problems related to convergence of Infinite Product.

Suggested Readings:

1. Ahlfors, L.V. Complex Analysis. 3rd edition, McGraw-Hill, 2017.
2. Alpay, D. A Complex Analysis Problem Book. Birkhäuser, 2016.

3. Churchill, R. V. and Brown, J. W. Complex Variables and Applications. 9th ed tion, McGraw Hill Education, 2014.
4. Edward,S. B. and Snider, Arthur D. Fundamental of Complex Analysis with Applications to Engineering and Sciences. Pearson Education, 2014.
5. Lang, S. Complex Variable. Springer, 2013.
6. Conway J. B. Functions of One Complex Variable. Springer, 2000.

Course Code	MATHCC0422	Course Name	Topology
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	This course aims to teach the fundamentals of point set topology and constitute an awareness of need for the topology in Mathematics. It is a central of modern analysis, and many further interesting generalizations of metric space have been developed.		
Course Outcomes:	After completing this course, student is expected to learn the following 1: Construct topological spaces from metric spaces and using general properties of neighbourhoods, open sets, close sets, basis and sub-basis 2: Apply the properties of open sets, close sets, interior points, accumulation points and derived sets in deriving the proofs of various theorems 3: Understand the concepts of countable spaces and separable spaces 4: Learn the concepts and properties of the compact and connected topological spaces		

COURSE SYLLABUS

Units	Content of Each unit
1	Definition and examples of topological spaces, basis and sub-basis, open sets, closed sets, neighbourhoods, interior points, limit points, boundary points, exterior points of a set, closure of a set, derivedset, Hausdorff spaces.
2	Continuous functions, Countable and uncountable sets. Infinite sets and the Axiom of Choice with Cardinal numbers and its arithmetic.Schroeder-Bernstein theorem. Cantor's theorem and the continuum hypothesis. Zom's lemma. Well-ordering theorem, open and closed mappings, homeomorphism, Tychonoff theorem.
3	Compactness and finite intersection property. Sequentiallyand countably compact sets. Local compactness and one point compactification. Stone vech compactification.
4	Separation axioms, T0, T1, T2, Lindelof spaces, regular and normal spaces. Urysohn Lemma, metrization theorems (Urysohnmetrization, Nagata-Smirnov metrization heorem), Tietze extension theorem, compactification.

Suggested Readings:

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

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Course Code	**MATHCC0423**	**Course Name**	**Project/Survey/Dissertation/Industrial Training andViva-Voce**
Programme	M.A./M.Sc. Mathematics	Credits	6
Total Marks	100		
Course Objective	The purpose of this course is to enhance writing and communication skills,presentation. How to present subject and ongoing researches.		
Course Outcomes:	After completing this course, student is expected to learn the following 1: Will be able to present research work in the field. 2: Get ability to write subject in own way.3: Skills to know future of the subject. 4: Get knowledge of preparing Dissertation, Thesis and Books.		

Pattern

1	The Student will submit two copies of the project/dissertation/survey/industrial training in the department at the end of the semester. Project/dissertation/survey/industrial training will be evaluated by one internal and one external examiner jointly, and a viva-voce examination.
2	One of the teacher will be chosen as supervisor under whose guidance the student will complete is project work/ Project/dissertation/survey/industrial training

Discipline Centric Elective Courses

Course Code	**MATHDCEC0424&0425A**	**Course Name**	**Advanced Discrete Mathematics**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The main objective of the course is to introduce concepts of mathematical logic, Lattice and graph theory and to give a brief introduction of Boolean algebra, bipartite graphs and trees and studying for their applications in real life.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Analyse logical propositions using truth tables. 2: Understand the concept of lattice. 3: Learn about the applications of Boolean algebra in switching theory.		
	4: Use the concept of planar graphs, trees and study for their properties.		

Units	Content of Each unit
1	Formal Logic: Statements, proposition, symbolic representation and tautologies, quantifiers, proposition logic. Lattices: Lattices as partially ordered sets, their properties, lattices as algebraic systems, some special lattices, e.g., complete, complemented and distributive lattices, some special lattices e.g., bounded, complemented & distributive lattices.
2	Boolean Algebra: Boolean algebra as lattices, various Boolean identities, the switching algebra example, join - irreducible elements, atoms and minterms, Boolean Forms and their equivalence, minterm Boolean forms, sum of products canonical forms, minimization of Boolean functions, applications of Boolean algebra to switching theory (using AND, OR and NOT gates), Karnaugh maps.
3	Trees, Binary tree, Spanning tree, Euler's Formula for connected Planar Graphs. Complete& Complete Bibarate Graphs. Kuratowski's Theorem (statement only) and its use, Cut-sets, Fundamental Cut-sets, and Cycles. Minimal Spanning Trees and Kruskal s Algorithm. Matrix Representations of Graphs, Incidence Matrix, Circuit Matrix, Cut-Set Matrix, Adjacency Matrix, Euler's Theorem on the Existence of Eulerian Paths and Circuits. Directed Graphs. In degree and Out degree of a vertex. Weighted Graphs. Dijkstra's Algorithm
4	Introductory Computability Theory-Finite State Machines and their Transition Table Diagrams, Finite Automata, Moore and Mealy Machines, Grammars and Languages-Phrase-Structure Grammars. Rewiting Rules, Derivations. SententialForms. Language generated by a Grammar. Regular, Context-Free, and Context Sensitive Grammars and Languages. Regular sets, Regular Expressions and the Pumping Lemma.Kleene's Theorem.

Suggested Readings:

1. Tremblay, J.P. and Manohar, R. Discrete Mathematical Structures with Applications to Computer Science. Ist edition McGraw Hill Book Co., 2017.
2. Lepschutz, S. and Lipson, M. Linear Algebra. 5th edition, Tata McGraw Hill 2012.
3. Ram, B. Discrete Mathematics. Pearson Education, 2012.
4. Kenneth H. R. Discrete Mathematics and Its Applications, 7th edition, Tata McGraw Hill, 2011.
5. Liu, C. L. Elements of Discrete Mathematics. Tata McGraw Hill, 2000.

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Course Code	MATHDCEC0424&425B	Course Name	Differential Geometry
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	In this course, students will be imparted knowledge to enable them to understand several concepts of Differential Geometry such as space curves, surfaces, curvatures, torsion, developables and geodesics.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Learn about the concepts of curvature, torsion, involutes and evolutes. 2: Familiarize with several concepts of tangent plane, Helicoids, metric and direction coefficients. 3: Understand the concepts of developable surfaces.		
	4: Use the several notions of curvatures such as geodesic curvature and Gaussian curvatures.		

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COURSE SYLLABUS

Units	Content of Each unit
1	Tensor Algebra: Difference between tensor and vector, Contraction, Inner Product, Symmetric and skew-symmetric tensors, Reciprocal symmetric tensor, Relative tensor, Alternate tensor, Isotropic tensor, Christoffel Symbols and Covariant differentiation, Ricci tensor, Bianchi's identity.
2	Space Curves: Metric tensor of the Euclidean space of three dimensions, Tangent to a curve, Osculating plane, Serret Frenet formulae, Fundamental planes, Curvature of a curve, Torsion of a curve, Contact between curves and surfaces, Locus of centre of spherical curvature, Spherical Indicatrix, Tangent surface, involutes and evolutes, Helix.
3	Surfaces in Space: Parametric Transformation, Curves on a surface, Tangent plane and normal to the surface, First fundamental quadratic form of the surface, Angle between two parametric curves, Angle between a parametric curve and any general curve of the surface, Orthogonal Trajectories, Second fundamental tensor, Weingarten formulae
4	The Normal Curvature of a surface: Normal curvature of a surface, Principal directions, Principal curvatures, Lines of curvature on a surface, Conjugate directions on a surface, Asymptotic direction at a point of a surface, Mean curvature, Gaussian curvature, Minimal surface, Gauss characteristic equation, Mainardi-Codazzi equations . Geodesics: Normal property of geodesics, Torsion of a geodesic, Geodesic torsion of a curve, Geodesic curvature of a curve.

Suggested Readings:

1. Weatherburn, C. E. Differential Geometry of Three Dimensions, Cambridge University Press, 2016.
2. Graustein, W. C. Differential Geometry. Courier Corporation, 2012.
3. Wilmore T. J. An Introduction to Differential Geometry, Dover Publications Inc , 2012.
4. Pressley, A. Elementary Differential Geometry. Springer, 2002.

Course Code	**MATHDCEC0424&425C**	**Course Name**	**Advanced Abstract Algebra**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The main objective of this course is to encourage students to develop a working knowledge of the central ideas of modules like cyclic modules, simple, semi-simple modules uniform modules, primary modules and theory of Noetherian and Artinian modules.		

Course Outcomes:	After completing this course, student is expected to learn the following: 1: Explain the fundamental concepts of modules and their role in modern mathematicsand applied contexts. 2: Demonstrate accurate and efficient use of finitely generated Abelian groups. 3: Apply the theorems: fundamental structure theorem of finitely generated modules over principal ideal domain, Noether- Lasker theorem, Hilbert bass theorem and Wedderburn - Artin theorem, Maschk's theorem CO4: Solve the problem using Nilradical and Jacobson radicals, operations on ideals, extension and contractions applied to diverse situations in physics, engineering and other mathematical contexts.

COURSE SYLLABUS

Units	Content of Each unit
1	Cyclic modules, simple and semi-simple modules, Schur's lemma, free modules, fundamental structure theorem of finitely generated modules over principal ideal domain and its applicationsto finitely generated Abelian groups.
2	Uniform modules, primary modules and Noether- Lasker theorem, Noetherian and Artinianmodules and rings with simple properties and examples.
3	Nilpotent ideals in Noetherian and Artinian rings, Hilbert basis theorem, Nakayama's lemma,Nilradical and Jacobson radicals, operations on ideals, extension and contraction.
4	Hom(R,R), opposite rings, Wedderburn-Artin theorem, Maschk's theorem, equivalent statement for left Artinian rings having non-zero nilpotent ideals.

Suggested Readings:

Rotman, J. J.Advanced Modern Algebra. 3rd edition. American Mathematical Soc., 2015.
Atiyah, M. F. and Macdonald, I. G. Introduction to Commutative Rings. Sarat Book House, 2007.
Curtis, C. W. and Reiner, I. Representation Theory of finite Groups and Associative Algebras.American Mathematical Society, 2006.
Lam, T. Y. Lectures on Modules and Rings. GTM Vol. 189, Springer-Verlag, 1999.
Bhattacharya,P. B., Jain, S. K. and Nagpaul, S. R. Basic Abstract Algebra. 2 nd edition, CambridgeUniversity Press, Indian edition, 1997.
Anderson, F. W. and Fuller, K. R. Rings and Categories of Modules. Springer-Verlag New York,1992.
Cohn, P. M. Algebra, Vols. I, II & III, John Wiley & Sons, (Vol. I-1982, Vol. II- 1989, Vol-III1991.

Minor Elective Courses

Course Code	MATHMEC0426A	**Course Name**	**Mathematical Modelling**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objectives of this course are to: • Enable students understand how mathematical models are formulated, solved and interpreted. • Make students appreciate the power and limitations of mathematics in solving practical real-life problems. • Equip students with the basic mathematical modelling skills.		

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Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand what a mathematical model is and explain the series of steps involved in a mathematical modelling process. 2: Use applications of mathematical modelling through difference equations. 3: Understand and apply the concept of mathematical modelling through difference equations in population dynamics, genetics and probability theory. 4: Apply the concept of mathematical modelling through graph theory

COURSE SYLLABUS

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

Suggested Readings:

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

Course Code	MATHMEC0426B	**Course Name**	**Number Theory**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL

Course Objective	The purpose of the course is to give a simple account of classica number theory, prepare students to graduate-level courses in number theory and algebra, and to demonstrate applications of number theory. In this course, students will have a working knowledge of the fundamental definitions and theorems of elementary number theory, be able to work with congruence's, solve congruence equations and systems of equations with one and more variables, and be literate in the language and notation of number theory.
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the properties of divisibility and prime numbers, compute the greatest common divisor and least common multiples and handle linear Diophantine equations 2: Use the operations with congruence's, linear and non-linear congruence equations 3: Apply the theorems: Chinese Remainder Theorem, Lagrange theorem, Fermat's theorem, Wilson's theorem 4: Analyse arithmetic functions in areas of mathematics

COURSE SYLLABUS

Units	Content of Each unit
1	Representation of the real numbers by decimals, divisibility, G.C.D and L.C.M., primes, Fermat numbers, congruences and residues, theorems of Euler, Fermat and Wilson, solutions of congruences, linear congruences, Chinese remainder theorem.
2	Arithmetical functions $\varphi(n)$, $\mu(n)$ and $d(n)$ and $\sigma(n)$, Mobius inversion formula, congruences of higher degree, congruences of prime power modulli and prime modulus, power residue.
3	Quadratic residue, Legendre symbols, lemma of Gauss and reciprocity law. Jacobi symbols, irrational numbers, irrationality of e and π. Finite continued fractions, simple continued fractions, infinite simple continued fractions.
4	Periodic continued fractions, approximation of irrational numbers by convergent, best possible approximation, Farey series, rational approximation, Pell's equations, Hurwitz theorem, Lagrange four square theorem.

Suggested Readings:

1. Apostol, T. M. Introduction to Analytic Number Theory. Springer 2014.
2. Niven, I. and Zuckerman, H. S. Introduction to the Theory of Numbers. John Wiley & Sons, 2008.
3. Burton, D. M. Elementary Number Theory. Tata McGraw Hill Publishing House, 2006.
4. Hardy, G. H. and Wright, E. M. Theory of Numbers. Oxford Science Publications, 2003.
5. Davenport, H. Higher Arithmetic. Cambridge University Press, 1999.

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SEMESTER-III CC Course

Course Code	MATHCC0431	Course Name	Partial Differential Equation with Applications
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		

Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objectives of this course are to: • Enable students understand how general PDEs solved Make students appreciate the power and limitations of numerical solutions of PDEs.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the solution of first order PDEs by characteristics method,Hamilton Jacobi's equations, Hopf-Lax formula etc. 2:Use applications of various solutions methods to solvePDEs. 3: Understand and apply similarity solution methods. 4: Apply different methods to find numerical solutions of Elliptic, Parabolic and Hyperbolic equations.		

COURSE SYLLABUS

Units	Content of Each unit
1	Green Function, Green function for Laplace equation, Harmonic function's properties, One and two dimensional wave equations, Heat equation, Method of separation of variables, Solution of Laplace equations in different co-ordinates system.
2	Non-linear First Order PDEs: Complete Integrals, Envelopes Characteristics, Hamilton-Jacobi Equations (Characteristic for the Hamilton-Jacobi Equation, Calculus of Variations, Hamilton's ODEs, Legendre's Transform, Hopf-Lax Formula, Weak Solution, Uniqueness), Conservation Laws (Lax-Oleinik Formula)
3	Solutions of PDEs by using separation of Variables Methods, Solution of PDEs by TransformMethods, Fourier Transform, Laplace Transform, Hankel Transform, Melin Transorm, Hopf-Cole Transformation, Hodograph Transform, Legendre Transform, Potential Function Technique, Burger Equation, Cauchy-Kovalevskaya Theorem.
4	Numerical Methods for Solving PDEs: Deriving difference equations, Finite Difference Approximations to Derivatives, Elliptic Equations, Laplacian Difference Equation, Solution of Laplace Equation, Liebmann's Iterative Methods, Poisson's Equation, Parabolic Equations, Heat Conduction Equation, Bender-Schmidt Method, Explicit Method, The Crank-Nicolson Implicit Method, Hyperbolic Equations, Solution of HyperbolicEquations.

Suggested Readings:

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

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Course Code	MATHCC0432	Course Name	Operations Research
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	This course is designed to introduce basic optimization techniques in order to get best results from a set of several possible solutions of different problems viz. linear programming problems, transportation problem, assignment problem and unconstrained and constrained problems etc.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand linear programming problems and to find their solutions by using different method. 2: Understand the network problems. 3: Understand and solve different queuing models. 4. Find optimal solution of linear programming model using Game Theory. Also learn about sequencing problems.		

COURSE SYLLABUS

Units	Content of Each unit
1	Linear Programming-Simplex and revised simplex Method, Dual Simplex method, Goal programming.
2	Network analysis, shortest path problem, Minimum Spinning tree, Maximum flow problem, Minimum cost flow problem, Project planning and control with PERT-CPM.
3	Queuing models: basic components of a queuing system, general birth-death equations, Integer Programming-Branch and Bound Technique.
4	Game theory: two persons zero sum game, game with saddle points, rule of dominance; algebraic, graphical and linear programming, concept of mixed strategy. Sequencing problems: processing of n jobs through 2 machines, n jobs through 3 machines, 2 jobs through m machines, n jobs through m machines.

Suggested Readings:

1. Besaint, W.H. and Ramsey, A.S. A Treatise on Hydromechanics Part Ihydrostatics, Andesite Press, 2017.
2. Kundu, P.K., Cohen, I. M. and Dowling, R. D. Fluid Mechanics, 6th edition, Academic Press, 2015.
3. O'Neil, M. E., and Chorlton, F. Ideal and Incompressible Fluid Dynamics. Ellis Horwood Ltd, 1986.
4. Yuan, S.W. Foundations of Fluid Mechanics. Prentice Hall of India Private Limited, New Delhi, 1976.
5. Curle, N. and Davies, H. J. Modern Fluid Dynamics.Vol1, D Van Nostrand Company Ltd, London, 1968.

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Course Code	MATHCC0433	Course Name	Functional Analysis
Programme	M.A./M.Sc. Mathematics	Credits	4

Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	To familiarize with the basic tools of Functional Analysis involving normed spaces, Banach spaces and Hilbert spaces, their properties dependent on the dimension and the bounded linear operators from one space to another.		
Course Outcomes:	After completing this course, student is expected to learn the following 1: Verify the requirements of a norm, completeness with respect to a norm, relation between compactness and dimension of a space, check boundedness of a linear operator and relate to continuity, convergence of operators by using a suitable norm, compute the dual spaces. 2: Distinguish between Banach spaces and Hilbert spaces, decompose a Hilbert space in terms of orthogonal complements.		
	3: Check totality of orthonormal sets and sequences, represent a bounded linear functional in terms of inner product, classify operators into self-adjoint, unitary and normal operators. 4: Extend a linear functional under suitable conditions, compute adjoint of operators, check reflexivity of a space, ability to apply uniform boundedness theorem, open mapping theorem and closed graph theorem, check the convergence of operators and functional and weak and strong convergence of sequences.		

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COURSE SYLLABUS

Units	Content of Each unit
1	Metric Space, Euclidean Space, Pseudo-metric, sequences, Cauchy Sequences, Complete metric spaces and examples, Dimension of a linear space, Baire's theorem, Cantor intersection theorem and Banach fixed point principle, normed linear spaces.
2	Banach spaces : Normed Linear Space, Banach spaces, examples of Banach spaces and subspaces, Sequence of Scalars, Holder's Inequality, Minkowski's Inequality, Cauchy's Inequality, Euclidean and unitary space, Subspaces and Quotient Spaces of Banach Spaces, Riesz-Fisher Theorem.
3	Hilbert spaces : Inner Product Spaces, Hilbert spaces and examples, Schwarz Inequality, Parallelogram Law, Convex sets, Orthogonality, Pythagorean Theorem, Projection Theorem, Orthonormal sets, Bessel's inequality, Parseval's theorem, Characterization theorem for complete orthogonal sets, Riesz representation theorem for continuous linear functionals on a Hilbert space.
4	Adjoint operators, self-adjoint operators, Positive operator, normal and unitary operators, weak and strong convergence, completely continuous operators, Hahn-Banach theorem and its applications, uniform boundedness principle, open mapping theorem, closed graph theorem.

Suggested Readings:

1. Simmons, G. F. Introduction to Topology and Modern Analysis. McGraw-Hill Pvt. Ltd. 2016.
2. Bachman, G. and Narici, L. Functional Analysis. Courier Corporation, 2012.
3. Conway, J. B. A Course in Functional Analysis. Springer, 2010.
4. Kreyszig, E. Introductory Functional Analysis with Applications. John Wiley, 2007.
5. Royden, H. L. Real Analysis. MacMillan Publishing Co., Inc., New York, 4th edition, 1993.

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Course Code	MATHCC0434		Course Name	Seminar Presentation and Viva-Voce
Programme	M.A./M.Sc. Mathematics		Credits	6
Total Marks	100 (Class Int. Exam-30 marks, Univ. Exam-70 marks			
Examination	3 Hours	Pre-requisite of course		NIL
Course Objective	The purpose of this course is to enhance communication skills and presentation. How to face interviews in competitions.			
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Will be able to present the subject in interviews. 2: Get ability to face interviews. 3: Skills to write subject in own way. 4: Get knowledge of preparing Dissertation, Thesis and Books.			

Pattern

1	A : Viva and Presentation of assigned / selected problem /topic by each student in each of the other four papers to be evaluated by one Internal & one External Examiner.

Discipline Centric Elective Courses

Course Code	MATHDCEC0435A	Course Name	Difference Equations
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to introduce the difference equations, solutions. Fundamental theorems for existence and uniqueness difference equations.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the occurring of difference equations and linear difference equations. Also will be able to solve these equations 2: Understand the non-linear difference equations and their linearization. 3: Understand the System of difference equations. 4. Understand the nonlinear difference equations and their systems.		

COURSE SYLLABUS

Units	Content of Each unit
1	Introduction, difference calculus, difference operators, Greens function, approximate summations, Linear difference equations of first order, existence and uniqueness of solutions, linear difference equations with constant coefficients,
2	Equations with variables coefficients, Non-linear equation that can be linearised, The z-transform, Properties of z-transform, Initial and final value theorem, General solution of second order homogeneous difference equation, Matrix method for solving linear difference equations.
3	Systems of linear difference equations, qualitative behavior of solutions to linear difference equations, Generating function, Properties of generating function, Exponential generating function, Recurrence relation.

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4	Nonlinear difference equations (Map): Steady states and their stability, the logistic difference equation, systems of nonlinear difference equations, stability criteria for second order equations, stability criteria for higher order system, Critical points, Lagrange's identity, Green's formula, Abel's formula.

Suggested Readings:

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

Course Code	**MATHDCEC0435B**	**Course Name**	**Fuzzy set Theory**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The course aims to introduce students to fundamental concepts in fuzzy sets, fuzzy relations, arithmetic operations on fuzzy sets, probability theory, fuzzy logic and its applications.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Construct appropriate fuzzy numbers corresponding to uncertain and inconsistent collected data. 2: Understand the basic concepts of t- norms, t- conforms and operation of - cut interval. 3: Use the concepts of approximation of triangular fuzzy number, operations of trapezoidal fuzzy number, bell shape fuzzy number, crisp function and its applications. 4: Analyse the Integration and differentiation of fuzzy function product set, and understand the basic concepts of composition of fuzzy relation, fuzzy graph, projection and cylindrical extension		

COURSE SYLLABUS

Units	Content of Each unit
1	Concepts of fuzzy set, standard operations of fuzzy set, fuzzy complement. fuzzy union, fuzzy intersection, other operations in fuzzy set, t- norms and tconorms. Interval, fuzzy number, operation of interval, operation of - cut interval, examples of fuzzy number operation.
2	Definition of triangular fuzzy number, operation of triangular fuzzy number, operation of general fuzzy numbers, approximation of triangular fuzzy number, operations of trapezoidal fuzzy number, bell shape fuzzy number, function with fuzzy constraint, propagation of fuzziness by crisp function, fuzzifying function of crisp variable, maximizing and minimizing set, maximum value of crisp function.
3	Integration and differentiation of fuzzy function product set, definition of relation, characteristics of relation, representation methods of relations, operations on relations, path and connectivity in graph, fundamental properties, equivalence relation, compatibility relation, pre-order relation, order relation, definition and examples of fuzzy relation, fuzzy matrix, operations on fuzzy relation.
4	Composition of fuzzy relation, - cut of fuzzy relation, projection and cylindrical extension, extension by relation, extension principle, extension by fuzzy relation, fuzzy distance between fuzzy sets, graph and fuzzy graph, fuzzy graph and fuzzy relation, - cut of fuzzy graph.

Suggested Readings:

1. Mohan, C. An Introduction to Fuzzy Set Theory and Fuzzy Logic. Anshan Publishers, 2015.
2. Lee, K. H. First Course on Fuzzy Theory and Applications. Springer International Edition, 2005.
3. Yen, J., Langari, R. Fuzzy Logic - Intelligence, Control and Information. Pearson Education, 1999.
4. Zimmerman, H.J. Fuzzy Set Theory and its Applications. Allied Publishers Ltd., New Delhi, 1991.

नरेन्द्र
(डा० नरेन्द्र शर्मा)

Minor Elective Courses for M.Sc. (Mathematics)

Course Code	**MATHMEC0436A**	**Course Name**	**Measure Theory and Integration**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	Measure theory provides a foundation for many branches of mathematics such as harmonic analysis, ergodic theory, theory of partial differential equations and probability theory. It is a central, extremely useful part of modern analysis, and many further interesting generalizations of measure theory have been developed.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Use the concepts of measurable set and measurable function 2: State and explain the construction of the Lebesgue integral and use it 3: Apply the theorems of monotone and dominated convergence and Fatou's lemma 4: Describe the construction of product measure and to apply Fubini's theorem		

COURSE SYLLABUS

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

Suggested Readings:

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

Course Code	**MATHMEC0436B**	**Course Name**	**Introduction to Cryptography**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The purpose of the course is to give a simple account of cryptography. Upon completion of the course, students will have a working knowledge of the fundamental definitions and theorems of elementary congruences, solve congruence equations and systems of equations with one and more variables. They will understand the language, notation of Caesar Cipher and explored to cryptography. We will also discussion on Diffie-Hellman RSA public key cryptosystem.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the operations with congruence's, linear and non-linear congruence equations. 2: Use the basics of RSA security and be able to break the simplest instances and analyse the basic concepts of remote coin flipping, elliptic curve based cryptography. 3: Apply the theorems: Fermat's last theorem, prime number theorem and zeta function. 4: Understand and use the numbers: Perfect numbers, Fermat numbers, Mersenne primes and amicable numbers, Fibonacci numbers.		

COURSE SYLLABUS

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

Suggested Readings:

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

SEMESTER-IV

Course code	**MATHCC0441**	**Course Name**	**Mathematical Statistics**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The aim of the course is to enable the students with understanding of various types of measures, various types of probability distributions and testing of hypothesis problems. It aims to equip the students with standard concepts of statistical techniques and their utilization.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Explore the basic ideas about measures of central tendency, dispersion, skewness and kurtosis with their applications and basic idea about probability theory. 2: Demonstrate the understanding of random variable, expectation, variance and some discrete distributions. 3: Explain the different types of continuous distributions and their utilization. 4: Deal with formulation of hypotheses as per situations and their testing.		

COURSE SYLLABUS

Units	Content of Each unit
1	Measures of central tendency and dispersion, moments, measures of skewness and kurtosis, correlation and regression. axiomatic approach to the theory of probability, sample space, additive and multiplicative law of probability, conditional probability. Definition anc properties of random variables, discrete and continuous random variables, probability mass and density functions, distribution function. Concepts of bivariate random variables, Bayes theorem, Booles Inequality, Mathematical expectation: Definition and its properties. variance, covariance, moment generating function- definitions and their properties.
2	Discrete distributions: Binomial, Poisson and Geometric, Negative binomial, Power series distributions with their properties.
3	Continuous distributions: uniform, exponential, gamma, beeta and normal distributions with their properties, Central Limit Theorem, Chi-Square distribution.
4	Statistical estimation, Theory of estimetors, Max. Likelihood, Testing of hypothesis: Null and alternative hypotheses, simple andcomposite hypotheses, two types of errors, t, F and Chi-Square as sampling distribution and applications.

Suggested Readings:

1. Meyer, P. L. Introductory Probability and Statistical Applications. 2nd edition, Addison-Wesley Publishing Company, 2017.
2. Gupta, S. C. and Kapoor, V. K. Fundamentals of Mathematical Statistics. Sultan Chand & Sons, 2014.
3. Mood, A. M., Graybill, F. A. and Boes, D. C. Introduction to the Theory of Statistics, Tata McGraw Hill, 2014.
4. Spiegel, M. R., Schiller, J. J. and Srinivasan, R. A. Probability and Statistics. Tata McGraw-Hill, 2014.
5. Baisnab, A. P. and Jas, M. Element of Probability and Statistics, Tata McGraw Hill, 1993.

नरेन्द्र
(डा० (नरेन्द्र) शर्मा)

Course Code	MATHCC0442	Course Name	Advanced Fluid Dynamics
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to provide a treatment of topics in magneto hydrodynamics, boundary layer theory and an appreciation of their application to real world problems.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the stress tensors 2. Understand the vortex motion 3. Understand the boundary layer theory. 4: Understand the magneto-hydrodynamics.		

COURSE SYLLABUS

Units	Content of Each unit
1	Motion of sphere through liquid at rest at infinity, Liquid streaming past a fixed sphere, Motion of concentric sphere, Three dimensional source and sink, Doublet, Image of source with respect to sphere and plane.
2	Vortexmotion and its elementary properties, Vortex filament, vortex doublet, vortex pair, image of vortex with respect to plane and circle, Kelvin's proof of permanence Motions due to circular and rectilinear vortices, Spiral vortex, Rectilinear vortex, Karman's vortex street, Kirchhoff vortex theorem.
3	Boundary Layer Theory: Prandtls' boundary layer theory and its importance, Drag and lift, The boundary layer equation in two dimensional flow. The boundary layer flow over a flat plate. Karman's integral equation, Application of the boundary layer in absence of pressure gradient. Application of the Karman'sintegral equation to boundary layer with pressure gradient : Karman momentum integral equation, Vorticity equation.
4	Stresses in Fluids: Strain and stress tensor, symmetry of stress tensor, transformation of strain components in two dimension, principal stress and principal stress direction, Navier Stokes equation, Reynold's Number, Prandtl number, Weber number, Steady flow between parallel planes, Laminar flow between parallel plates, Steady flow through a cylindrical pipe, Hagen-Poiseuille flow.

Suggested Readings:

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

नरेन्द्र
(डा० एन० के० शर्मा)

Course Code	MATHCC0443	Course Name	**Project/Dissertation/Survey/Industrial Training and Viva-Voce**
Programme	M.A./M.Sc. Mathematics	Credits	6
Total Marks	100		

Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The purpose of this course is to enhance writing and communication skills, presentation. How to present subject and ongoing researches.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Will be able to present research work in the field. 2: Get ability to write subject in own way. 3: Skills to know future of the subject. 4: Get knowledge of preparing Dissertation, Thesis and Books.		

Pattern

1	The Student will submit two copies of the project/dissertation/survey/industrial training in the department at the end of the semester. Project/dissertation/survey/industrial training will be evaluated by one internal and one external examiner jointly, and a viva-voce examination.
2	One of the teacher will be chosen as supervisor under whose guidance the student will complete is project work/ Project/dissertation/survey/industrial training.

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Discipline Centric Elective Courses

Course code	**MATHDCEC0444&445A**	**Course Name**	**Integral Equations**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	In this course we study in detail about integral equations and calculus of variations. Integral equations find numerous applications in real life physical problems. The main objective of the course is to make the learner familiarize with resolvent kernel, successive approximation, solution of homogeneous Fredholm integral equation for solving integral equations and variational problems. Differential equations can be studied for their solutions by transforming them into integro-differential equations using Laplace transform.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Use the concept of different kernels and techniques for solving various kinds of integral equations. 2: Find the solutions of Volterra integral equations using Neumann series method. 3: Understand the relation between differential and integral equations. 4: Understanding of Hilbert Schmidt theorem and solutions by using symmetric kernels.		

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COURSE SYLLABUS

Units	Content of Each unit
1	Solution of Fredholm Integral Equations: Solution of Homogeneous Fredholm Integral Equation of the second kind with separable, Orthogonality and Reality of Eigen functions, Eigen values of Symmetric kernel, Determination of Eigen functions, Determination of Eigen values and Eigen functions of homogeneous equations, Fredholm Integral Equation with separable kernel, Complex Hilbert Space, Orthonormal System of functions, Gram-Schmidt Orthonormalization Process, Schwarz Inequality, Bessel's Inequality, Riesz-Fischer Theorem, Symmetric Kernel, Iterated Kernel, Mercer's Theorem, Hilbert's Theorem, Solution of Fredholm Integral Equation of first kind
2	Solution of Fredholm Integral Equation of second kind by Successive Substitution: Solution of Volterra Integral Equation of second kind by Successive Substitution, Solution of Fredholm Integral Equation of second kind by Successive Approximation, Reciprocal kernel, Determination of Iterated kernel and resolvent kernel, Method of Successive Approximation, Reciprocal Function, Volterra's Solution of Fredholm Integral Equation of second kind, Reciprocal kernel of Volterra Integral Equation, Determination of resolvent kernel of Volterra Integral Equation, Solution of Volterra Integral Equation, Integral Equation by Successive Approximation method
3	Classical Fredholm Theory: Fredholm's Fundamental Relations, Hadamard's Theorem, Convergence of Fredholm's Determinant and Fredholm First Minor, Fredholm Fundamental Theorems, Fredholm's Second Fundamental Theorems, Existence of Eigen value, Orthogonality Theorem
4	Integral Transform Method: Some special types of Integral Equations Application of Laplace Transform to determine the solutions of Volterra Integral Equation with Convolution type kernels, Abel Integral Equation, Fourier Transform, Application of Fourier Transform to determine the solutions of Singular Integral Equations, Mellin Transform, Fox's Integral Equation

Suggested Readings:

1. Wazwaz, A. M. A First Course in Integral Equations. 2 nd edition World Scientific Publishing Co. 2015.
2. Kanwal, R. P. Linear Integral Equation. Theory and Techniques. Academic Press, 2014.
3. Gelfand, I. M. and Fomin, S. V. Calculus of Variations. Courier Corporation, 2012.
4. Hildebrand, F. B. Method of Applied Mathematics, Courier Corporation, 2012.
5. Raisinghania M. D. Integral Equation & Boundary Value Problem. S. Chand Publishing, 2007.
6. Jerri, A. Introduction to Integral Equations with Applications, John Wiley & Sons, 1999.

Course code	**MATHDCEC0444&445B**	**Course Name**	**Theory of Elasticity**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	This course aims to familiarize the students with tensors and the principles and basic equations of elasticity. The course will expose the students to two dimensional problems in Cartesian and polar coordinates.		

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Course Outcomes:	After completing this course, student is expected to learn the following: 1: Use the indicial notation and knowledge of tensor 2: Analyse strain, stress and deformation 3: Understand the basic principles and field equations of linear elastic solids 4: Formulate the solution strategies of various two dimensional problems
	5: Analyse the propagation of surface waves

COURSE SYLLABUS

Units	Content of Each unit
1	Cartesian tensor: Coordinate transformation, Cartesian tensor of different order, sum or difference and product of two tensors. contraction theorem, quotient law, symmetric & skew symmetric tensors, Kronecker tensor, alternate tensor and relation between them, scalar invariant of second order tensor, eigen values & vectors of a symmetric second order tensor, gradient, divergence & curl of a tensor field. Analysis of strain: affine transformations, infinitesimal affine transformation, geometrical interpretation of the components of strain.
2	Strain quadric of Cauchy, principal strains and invariants, general infinitesimal deformation. Saint- Venant's equations of compatibility. Analysis of stress: stress tensor, equations of equilibrium, transformation of coordinates, stress quadric of Cauchy, principal stress and invariants, maximum normal and shear stresses.
3	Equations of elasticity: Generalized Hooke's law, homogeneous isotropic media, elastic moduli for isotropic media, equilibrium and dynamic equations for an isotropic elastic solid, strain energy function and its connection with Hooke's law, Beltrami-Michell compatibility equations.
4	Two-dimensional problems: Plane strain, plane stress, generalized plane stress, Airy's stress function, general solution of bi-harmonic equation, stresses and displacements in terms of complex potentials, propagation of waves in an isotropic elastic solid medium, waves of dilation and distortion, elastic surface waves such as Rayleigh and Love waves.

Suggested Readings:

1. Sadd, M. H. Elasticity: Theory, Applications and Numerics. Academic Press, 2014.
2. Love, A. E. H. A Treatise on Mathematical Theory of Elasticity. Cambridge [Eng.] University Press, 2013.
3. Timoshenko, S. P. and Goodier, J. N. Theory of Elasticity. New York McGraw-Hill, 2010.
4. Narayan, S. Text Book of Cartesian Tensors. S. Chand & Co., 1968.
5. Sokolnikoff, I. S. Mathematical Theory of Elasticity. McGraw-Hill Inc, 2nd edition, 1956.

Course code	**MATHDCEC0444&445C**	**Course Name**	**Tensors and General Relativity**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objectives of this course are to study tensor and general theory of relativity.		

Course Outcomes:	After completing this course, student is expected to learn the following:1: Understand tensor and symbols used for tensor. 2. Understands the Riemannian metric. 2: Understands the Einstein's field equations. 3: Understand the keplers law and Schwarzschild external solution.

COURSE SYLLABUS

Units	Content of Each unit
1	Transformation of coordinates, Tensors, Algebra of Tensors, Symmetric and skewsymmetric Tensors, Contraction of tensors and quotient law.
2	Riemannian metric, Christoffel Symbols, Covariant derivatives, Intrinsic derivatives and geodesics. Riemann-Christoffel curvature tensor and its symmetryproperties, Bianchi identities and Einstein tensor.
3	Review of the special theory of relativity and the Newtonian Theory of gravitation, Principles of equivalence and general covariance, geodesic principle, Newtoniar approximation of relativistic equations of motion. Einstein's field equations and its Newtonian approximation.
4	Schwarzschild external solution and its isotropic form, Planetary orbits and analogues of Kepler's Laws in general relativity. Advance of perihelion of a planet, Bending of light rays in gravitational field, gravitational red-shift of spectral lines. Radar echo delay.

Suggested Readings:

1. C. E. Weatherburn. An Introduction of Riemannian Geometry and Tensor Calculus, CambridgeUniversity, Press, 1950.
2. H. Stephani, Genereal Relativity. An Introduction of the theory of the gravitational field. CambridgeUniversity Press, 1982.
3. A. S. Eddington, The Mathematical Theory of Relativity, CambridgeUniversity, Press, 1965.

Course code	**MATHDCEC0444&445 D**	**Course Name**	**Information Theory-II**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to introduce basic and advanced topics in information theory. This course further explains the different types of entropies, codes, discrete and continuous channels and their applications.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the basic concepts of information theory, different types of entropies with their properties and applications. 2: Analyse how different coding techniques will perform in different situations. 3: Understand about discrete channels and their properties with applications.		
	4: Understand about continuous channels and their properties with applications.		

COURSE SYLLABUS

Units	Content of Each unit
1	Measure of information – axioms for a measure of uncertainty, the Shannon entropy and its properties. joint and conditional entropies, transformation and its properties, axiomatic characterization of the Shannon entropy due to Shannon and Fadeev.
2	Noiseless coding - ingredients of noiseless coding problem, uniquely decipherable codes, necessary and sufficient condition for the existence of instantaneous codes, construction of optimal codes.
3	Discrete memory less channel - classification of channels, information processed by a channel, calculation of channel capacity, decoding schemes the ideal observer, the fundamental theorem of information theory and its strong and weak converses.
4	Continuous channels - the time-discrete Gaussian channel, uncertainty of an absolutely continuous random variable, the converse to the coding theorem for time-discrete Gaussian channel, the time-continuous Gaussian channel, bandlimited channels.

Suggested Readings:

1. Ash, R. B. Information Theory. Courier Corporation, 2012.
2. Reza, F.M. An Introduction to Information Theory. Courier Corporation, 2012.
3. Hankerson, H. D., Harris, G. A. and Johnson, P. D. Introduction to Information Theory and Data Compression. Chapman and Hall/CRC, 2nd edition, 2003.
4. Aczel, J. and Daroczy, Z. On Measures of Information and their Characterizations. Academic Press, New York, 1975.

Course code	MATHDCEC0444&0445E	Course Name	Bio-Mathematics
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objective of this course is to introduce basic and advanced topics in information theory. This course further explains the different types of entropies, codes, discrete and continuous channels and their applications.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the basic concepts of information theory, different types of entropies with their properties and applications. 2: Analyse how different coding techniques will perform in different situations. 3: Understand about discrete channels and their properties with applications. 4: Understand about continuous channels and their properties with applications.		

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COURSE SYLLABUS

Units	Content of Each unit
1	Measure of information – axioms for a measure of uncertainty, the Shannon entropy and its properties. joint and conditional entropies, transformation and its properties, axiomatic characterization of the Shannon entropy due to Shannon and Fadeev.
2	Noiseless coding - ingredients of noiseless coding problem, uniquely decipherable codes, necessary and sufficient condition for the existence of instantaneous codes, construction of optimal codes.
3	Discrete memory less channel - classification of channels, information processed by a channel, calculation of channel capacity, decoding schemes the ideal observer, the fundamental theorem of information theory and its strong and weak converses.
4	Continuous channels - the time-discrete Gaussian channel, uncertainty of an absolutely continuous random variable, the converse to the coding theorem for time-d screte Gaussian channel, the time-continuous Gaussian channel, band-limited channels.

Suggested Readings:

1. Ash, R. B. Information Theory. Courier Corporation, 2012.
2. Reza, F.M. An Introduction to Information Theory. Courier Corporation, 2012.
3. Hankerson, H. D., Harris, G. A. and Johnson, P. D. Introduction to Information Theory and Data Compression. Chapman and Hall/CRC, 2nd edition, 2003.
4. Aczel, J. and Daroczy, Z. On Measures of Information and their Characterizations. Academic Press, New York, 1975.

Course code	MATHDCEC0444&0445F		Course Name	Mathematics for Finance and Insurance
Programme	M.A./M.Sc. Mathematics		Credits	4
Total Hours	60			
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)			
Examination	3 Hours	Pre-requisite of course	NIL	
Course Objective	This course introduces the basic concepts of Financial Management such as Insurance and Measurement of returns under uncertainty situations. The philosophy of this course is that Time value of Money - Interest rate and discount rate play a fundamental role in Life Insurance Mathematics – Construction of Morality Tables.			

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Course Outcomes:	After completing this course, student is expected to learn the following: 1: Demonstrate knowledge of the terminology related to nature, scope, goals, risks and decisions of financial management. 2: Predict various types of returns and risks in investments and take necessary protective measures for minimizing the risk. 3: Develop ability to understand, analyse and solve problems in bonds, finance and insurance. 4: Build skills for computation of premium of life insurance and claims for general insurance using probability distributions.

COURSE SYLLABUS

Units	Content of Each unit
I	Financial Management –overview. Nature and scope of financial management. Goals and main decisions of financial management. Difference between risk, Speculation and gambling. Time

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

Suggested Readings:

1. Ross, S. M. An Introduction to Mathematical Finance. Cambridge University Press, 2019.
2. Elliott, R. J. and Kopp, P. E. Mathematics of Financial Markets. Sprigner Verlag, New York Inc, 2018.
3. Damodaran, A. Corporate Finance - Theory and Practice. John Wiley & Sons, Inc, 2012.
4. Hull, J. C. Options, Futures, and Other Derivatives. Prentice-Hall of India Private Ltd, 2010.
5. Daykin, C. D., Pentikainen, T. and Pesonen, M. Practical Risk Theory for Actuaries. Chapman & Hall, 2008.
6. Dorfman, M. S. Introduction to Risk Management and Insurance. Prentice Hall, Englwood Cliffs, New Jersey, 1999.
7. Neftci, S. N. An Introduction to the Mathematics of Financial Derivatives. Academic Press, Inc, 1991

Course code	**MATHDCEC0444&0445G**		**Course Name**	**Wavelet Analysis**
Programme	M.A./M.Sc. Mathematics		Credits	4
Total Hours	60			
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)			
Examination	3 Hours	Pre-requisite of course		NIL
Course Objective	The course aim is to introduce a flexible system which provide stable reconstruction and analysis of functions (signals) and the construction of variety of orthonormal bases by applying operators on a single wavelet function			
Course Outcomes:	After completing this course, student is expected to learn the following: 1: Understand the approximation of functions (signals) by frame theory. 2: Use the applications of frames in stable analysis and decompositions of functions. 3: Learn the applications of wavelets in the construction of orthonormal bases by wavelets. 4: Analyse different types of transforms in term of operators.			

COURSE SYLLABUS

Units	Content of Each unit
1	Review of inner product spaces, orthonormal systems, frames in Cn , frames algorithms, frames and Bessel sequences in infinite dimensional Hilbert spaces, frame sequence, the Gram matrix associated with Bessel sequences.
2	Frames and operators, characterization of frames, dual frames, tight frames. Riesz bases, frames versus Riesz bases, conditions for a frame being a Riesz basis, frames containing a Riesz basis, perturbation of frames.
3	Wavelets, Haar wavelets, basic properties of the Haar scaling function, Haar decomposition and reconstruction algorithms, the Daubechies wavelets, wavelet bases, scaling function. multire solution analysis (MRA), construction of wavelets from MRA.
4	Windowed Fourier transform (WFT), continuous Fourier transform (CFT), continuous wavelet transform (CWT), comparison between CFT and CWT, continuous wavelet transform as an operator, inversion formula for continuous wavelet transform.

Suggested Readings:

1. Boggess, A. and Narcowich, F.J. A First Course in Wavelets and Fourier Analysis. John Wiley & amp; Sons, 2010.
2. Mallat, S. A Wavelet Tour of Signal Processing. Academic Press, 2009.
3. Han, D., Kornelson, K., Larson, D. and Weber, E. Frames for Undergraduates, Student Math. Lib., (AMS) Vol. 40, 2007.
4. Christensen, O. An Introduction to Frames and Riesz Bases. Birkhauser, 2003.
5. Harnendez, E. and Weiss, G. A First Course on Wavelets, CRC Press, 1996.

Course code	**MATHDCEC0444&0445H**	**Course Name**	**Differential Geometry of Manifolds**
Programme	M.A./M.Sc. Mathematics	Credits	4
Total Hours	60		
Total Marks	100 (Class Int. Exam.-30 marks, Univ. Exam.-70 marks)		
Examination	3 Hours	Pre-requisite of course	NIL
Course Objective	The objectives of this course are to study tensor and manifolds.		
Course Outcomes:	After completing this course, student is expected to learn the following: 1. Understand tensor and symbols used for tensor. 2. Understands the Riemannian metric. 3. Understands the Christoffels and Ricci tensor.		

নৈরেন্দ্র
(ডঃ নৃপেন্দ্র শৰ্মা)

COURSE SYLLABUS

Units	Content of Each unit
1	Transformation of coordinates, Tensors, Algebra of Tensors, Alternate tensor, Symmetric and skewsymmetric Tensors, Reciprocal and Relative tensors, Contraction of tensors and quotient law. Riemannian metric, Christoffel Symbols, Covariant derivatives, Intrinsic derivatives and geodesics. Riemann-Christoffel curvature tensor and its symmetry properties. Bianchi identities and Einstein tensor.
2	Ricci tensor, Riemannian curvature tensor of first and second kind, Definition and examples of differentiable manifolds. Tangent spaces, Immersions and imbedding of manifolds.
3	Riemannian manifolds: Length of a curve in Riemannian manifold, Magnitude of a vector in Riemannian manifold, Angle between two vectors in Riemannian manifold, Parallelism of vectors, Geodesics, Riemannian Coordinate system, Recurrent Riemannian manifold, Riemannian curvature, Einstein space.
4	Hypersurfaces: Generalised Gauss formulae, Normal curvature, Asymptotic line, Meunier's theorem, Weingarten equations. Lines of curvature. Generalized Gauss and Mainardi-Codazzi equations.

Suggested Readings:

1. R.S. Mishra, A course in tensors with applications to RiemannianGeometry, Pothishala (Pvt.) Ltd., 1965.
2. R.S. Mishra, Structures on a differentiable manifold and theirapplications, Chandrarna Prakashan, Allahabad, 1984.
3. B.B. Sinha, An Introduction to Modern Differential Geometry,Kalyani Publishers, New Delhi, 1982.
4. K. Yano and M. Kon, Structure of Manifolds, World ScientificPublishing Co. Pvt. Ltd., 1984.

नरेन्द्र
(डा० एन० के० शर्मा)