M. Sc. IN MATHEMATICS

UNDER THE FRAMEWORK OF

HONOURS SCHOOL SYSTEM

2023-2024

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PANJAB UNIVERSITY, CHANDIGARH

M.SC. IN MATHEMATICS

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ACADEMIC SESSION 2023-2024

CHOICE BASED CREDIT SYSTEM (CBCS)

CBCS is one of the important measures recommended by the University Grants Commission (UGC) to enhance academic standards and quality in higher education including innovation and improvements in curriculum, teaching-learning process, examinations and evaluation systems. CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising Core, and Discipline-Specific and Generic Elective courses. The performance of students in examinations will be evaluated following the grading system, which provides uniformity in the evaluation and computation of the Cumulative Grade Point Average (CGPA) based on student's performance in examinations. The grading system will facilitate student mobility across institutions within and across countries and also enable potential employers to assess the performance of students.

OBJECTIVES OF THE COURSE

The Master's programme aims to build strong foundations in core areas of higher mathematics in both the pure and applied areas. It is meant for students who would typically take up careers involving mathematical research or mathematical skills - in academia or in industry. The training imparted to the students helps them master the art of problem-solving, developing logical reasoning and computational capabilities which are essential traits in all walks of life.

PREAMBLE

The Department of Mathematics, Panjab University, Chandigarh was established in 1952 at Hoshiarpur and was shifted to Chandigarh in 1958. It has grown to be one of the best Departments of Mathematics of the Indian Universities. It has been recognized as the Centre for Advanced Studies in Mathematics since 1963 by the UGC. The Department participated in COSIP program during 1970-1983 and subsequently in the COSIST program from 1984-1989. The Department of Science and Technology, Govt. of India, had sponsored the Department for the FIST (Level-II) Program. The National Board for Higher Mathematics (NBHM) has granted the status of Regional Library to the Library of the Department and supports the Consortium for the online access of MathSciNet, for which the Department is the leading partner. The NBHM has been providing huge funds every year for books and journals. The Department is a source centre for Regional as well as National Mathematical Olympiad participants for the North-West Region. The Department is also a zonal centre for the award of NBHM, M.Sc. and PhD scholarships awarded by the Department of Atomic Energy, Govt. of India. The Department offers Bachelors, Masters and Doctoral degrees in key focus area of mathematical sciences.

M.Sc. (MATHEMATICS) under the framework of Honours School System

The M. Sc. (Mathematics) programme under the framework of the Honours School System is a two-year course divided into four semesters with a total of 80 credits. A student is required to complete 80 credits for the completion of the course and the award of the degree. In general, ve hours of theory lectures and two-hours tutorial per week equals 4 Credits. Subjects o ered in the M.Sc. programme divided into ve categories:

I.

CONTACT HOURS

1. Each of Core, Discipline Specific Elective, Skill Enhancement Course and Generic Elective subjects will consist of 60 lectures.
2. 60 lectures consists of 48 contact hours of teaching to be delivered exclusively by the teacher as per the scheduled time-table and 12 hours for the interaction, discussion, assignments and seminars (attended/delivered) by the students.
3. There will be teaching of 5 hours of theory classes and two hours of tutorials per week of each course.

COURSE STRUCTURE WITH CREDIT DETAILS

SEMESTER I: STUDENTS HAS TO DO FIVE COURSES EACH OF 4 CREDITS

SEMESTER -I (20 Credits)			
Nature of Course	Code	Name of Course	Credits
CORE { I	MAT-MC1	Field Theory & Commutative Algebra - I	4
(MAT-MC1 or MAT-MC2)	MAT-MC2	Groups and Rings	4
CORE { II	MAT-MC3	Topology	4
(MAT-MC3 or MAT-MC4)	MAT-MC4	Real Analysis	4
CORE { III	MAT-MC5	Advanced Complex Analysis	4
(MAT-MC5 or MAT-MC6)	MAT-MC6	Complex Analysis - I	4
CORE { IV	MAT-MC7	Linear Programming	4
CORE { V	MAT-MC8	Classical Mechanics	4

Note: The above mentioned courses will be offered to the students depending upon their background.

SEMESTER II: EACH STUDENT HAS TO DO FIVE COURSES EACH OF 4 CREDITS

SEMESTER -II (20 Credits)			
Nature of Course	Code	Name of Course	Credits
CORE { VI	MAT-MC9	Commutative Algebra - II	4
(MAT-MC9 or MAT-MC10)	MAT-MC10	Modules & Fields	4
CORE { VII	MAT-MC11	Number Theory - I	4
(MAT-MC11 or MAT-MC12)	MAT-MC12	Number Theory - II	4
CORE { VIII	MAT-MC13	Lebesgue Integration	4
CORE { IX	MAT-MC14	Ordinary Differential Equations	4
CORE { X	MAT-MC15	Probability Theory & Random Processes	4

Notes:

- The students who have studied MAT-MC1 in Semester I will have to take MAT-MC9 in Semester II.
- The students who have studied MAT-MC2 in Semester I will have to take MAT-MC10 in Semester II.
- The students who have studied a Number Theory course in their BSc are not eligible to opt for the course MAT-MC 11 Number Theory I. They will be offered MAT-MC 12 Number Theory II.

SEMESTER III: STUDENTS HAS TO DO FIVE COURSES EACH OF 4 CREDITS

SEMESTER -III (20 Credits)			
Nature of Course	Code	Name of Course	Credits
CORE { XI (MAT-MC16 or MAT-MC17)	MAT-MC16	Non-Commutative Ring Theory	4
	MAT-MC17	Linear Algebra and Commutative Algebra-I	4
CORE { XII (MAT-MC18 or MAT-MC19)	MAT-MC18	General Measure Theory	4
	MAT-MC19	Topology	4
CORE { XIII	MAT-MC20	Partial Differential Equations	4

Notes:

- The students who have studied MAT-MC1 and MAT-MC9 in Semesters I & II will have to take MAT-MC16 & MAT-MC18 in Semester III.
- The students who have studied MAT-MC2 and MAT-MC10 in Semesters I & II will have to take MAT-MC17 & MAT-MC19 in Semester III.
- Each student has to do two more courses among the choices given below

One DSE course	Discipline Specific Elective Courses, MAT-MDSE1 - MAT-MDSE9 (Table A)
One course from (DSEs, SECs, GEs, MOOCs)	Table A: Discipline Specific Elective Courses, MAT-MDSE1 - MAT-MDSE9 Table B: Skill Enhancement Courses (SEC), MAT-MSEC1 - MAT-MSEC4 Table C: Generic Elective Courses (GE) Table D: UGC MOOCS Courses (MOOC)

Table A: Discipline Specific Elective Courses

(Students have to choose one or two out of following depending upon their background)

Any DSE Course will be offered only if a minimum of 10 students opt for the same and depending upon the faculty available. The maximum limit of students in any DSE course is 40.

Course Code	Name of the Course	Credits
MAT-MDSE1	Computational Techniques - I	4
MAT-MDSE2	Algebraic Number Theory - I	4
MAT-MDSE3	Algebraic Coding Theory - I	4
MAT-MDSE5	Fluid Mechanics { I	4
MAT-MDSE6	Non Linear Programming	4
MAT-MDSE7	Mathematical Statistics	4
MAT-MDSE8	Mechanics of Solids - I	4
MAT-MDSE9	Numerical Methods for Di erential Equations	4
MAT-MDSE16	Topics in Integration Theory	4
MAT-MDSE17	Stochastic Processes	4
MAT-MDSE18	Stochastic Calculus	4

Table B: Skill Enhancement Courses

(If a student has opted for only one Discipline Speci c Elective Course, then he/she may choose one of the following (depending upon the background)

Course Code	Name of the Course	Credits
MAT-MSEC1	Set Theory	4
MAT-MSEC2	Network Analysis	4

Table C: Generic Elective Courses

If a student has opted for only one Discipline Speci c Elective Course and no Skill Enhancement Course, then he/she may choose one of the courses o ered by the following Departments of Panjab University at Masters level (depending upon the background):

- Department of Physics
- Department of Computer Science
- Department of Statistics
- Department of Economics

Table E: Discipline Speci c Elective Courses Students have to choose two or three out of following depending upon their background		
Course Code	Name of the Course	Credits
MAT-MDSE1 *	Computational Techniques - I	4
MAT-MDSE2 *	Algebraic Number Theory - I	4
MAT-MDSE3 *	Algebraic Coding Theory - I	4
MAT-MDSE5 *	Fluid Mechanics { I	4
MAT-MDSE6 *	Non Linear Programming	4
MAT-MDSE7 *	Mathematical Statistics	4
MAT-MDSE8 *	Mechanics of Solids - I	4
MAT-MDSE9 *	Numerical Methods for Di erential Equations	4
MAT-MDSE10	Computational Techniques - II	4
MAT-MDSE11	Algebraic Number Theory - II	4
MAT-MDSE12	Algebraic Coding Theory - II	4
MAT-MDSE13	Fluid Mechanics { II	4
MAT-MDSE14	Mechanics of Solids - II	4
MAT-MDSE15	Partial Di erential Equations - II	4
MAT-MDSE16*	Topics in Integration Theory	4
MAT-MDSE17*	Stochastic Processes	4
MAT-MDSE18*	Stochastic Calculus	4

Table F: Skill Enhancement Courses If a student has opted for only two Discipline Speci c Elective Courses, then he/she may choose one of the following courses depending upon the background. Skill Enhancement Course (SEC) can be chosen from the prescribed list. An SEC course will be o ered only if a minimum of 10 students opt for the same and depending upon the Faculty available.		
Course Code	Name of the Course	Credits
MAT-MSEC1*	Set Theory	4
MAT-MSEC2*	Network Analysis	4
MAT-MSEC3	Advanced Optimization Techniques	4

* Will be o ered if not run in Semester III.

GENERIC ELECTIVE COURSE AT MASTERS LEVEL (OFFERED BY MATHEMATICS DEPARTMENT) FOR THE STUDENTS OF OTHER DEPARTMENTS

MAT-MGE1: Abstract Algebra

Table G: Generic Elective Courses

If a student has opted for only two Discipline Speci c Elective Courses, then he/she may choose one of the courses o ered by the following Departments of Panjab University at Masters level (depending upon the background):

1. Department of Physics
2. Department of Computer Science
3. Department of Statistics
4. Department of Economics.

Table H: UGC MOOCS Courses

1. Before the beginning of the Semester the Academic Committee of the Department will decide

Percentage Marks (PM)	Numerical Grade	Grade Letter
95 PM		

Semester-I
Core Course-I
MAT-MC1: Field Theory & Commutative Algebra - I

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)
Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: The major aim of this course is the introduction of Field Theory and Galois Theory and their applications like solvability of polynomials by radicals. Besides this the course also introduces students to basic Commutative Algebra and paves the way to an advanced course MAT-MC9.

Unit-I

Field Theory: Fields, Examples, Algebraic and Transcendental elements, The degree of a eld extension, Adjunction of roots, Basic Straightedge and Compass Constructions, Splitting elds, Finite elds, Algebraically closed elds, Separable and purely inseparable extensions.

Unit-II

Perfect elds, Primitive elements, Lagrange's theorem on primitive elements, Normal extensions, Galois extensions, The fundamental theorem of Galois Theory.

Unit-III

Symmetric functions, Cyclotomic extensions, Cyclic extensions, Norms and traces, Quintic Equations and solvability by radicals.

Unit-IV

Review of Rings and ring homomorphism, Ideals, Quotient rings, Zero divisors, Nilpotent elements, Units, Prime ideals and maximal ideals, Nilradical and Jacobson radical, Operation on ideals, Extension and contraction of ideals, Modules and module homomorphisms, Submodule and quotient module, Operation on submodules, Direct sum and product, Finitely generated modules, Exact sequences, Tensor product of modules, Restriction and extension of scalars, Exactness property of the tensor product, Algebras, Tensor product of algebras.

Essential Textbooks:

(A) M. F. Atiyah and I. G. MacDonald, *Introduction to Commutative Algebra. Levant Books,* 2007.

(B) D. S. Dummit and R. M. Foote, *Abstract Algebra*, John Wiley & Sons, 2004.

Further Readings:

1. M. Artin, *Algebra*, Prentice Hall of India Pvt. 1994.
2. J. P. Escofier, *Galois Theory*, Graduate texts in Mathematics, 204, Springer-Verlag, (1^{st} ed), 2001.
3. I. S. Luthar and I. B. S. Passi, *Algebra, (vol.4), Field Theory*, Narosa 2004.
4. I. Stewart, Galois Theory, Capman & Hall, 1973.
5. O. Zariski and P. Samuel, *Commutative Algebra,* (vol. I and II), Springer, 1975.

OR

MAT-MC2: Group and Rings

Credits: 4

Contact hours: 60 7 hrs/per week (including Tutorials)
Max. Marks: 100 (Including Internal Assessment-20) Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: In this course some slightly advanced topics of Group Theory are discussed. The course also introduces Ring Theory and besides some basic constructions and results on rings, the course introduces factorization theory of domains and chain conditions.

Unit-I

Review of basic property of Groups, Dihedral groups, Symmetric groups and their congugacy classes, Simple groups and their examples. Simplicity of A_n (n 5), Sylow Theorems and their applications.

Unit-II

Direct Products, nite Abelian Groups, Fundamental Theorem on Finite Abelian Groups, Normal and Subnormal Series, Derived Series, Composition Series, Solvable Groups, Zassenhaus Lemma, Scherier's re nement theorem and Jordan-Holder Theorem.

Unit-III

Rings, Basic de nitions and Examples, Polynomial Rings, Matrix Rings, Group Rings, Ring Homomorphisms and Quotient Rings, Properties of Ideals, Rings of Fractions, The Chinese Remainder Theorem, Euclidean Domains.

Unit-IV

Further Readings:

1. M. Artin, *Algebra*, Prentice Hall of India, 1994.
2. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, *Basic Abstract Algebra*, (2^{nd} ed),Cambridge University Press, 2002.
3. W. Burnside, *The Theory of Groups of Finite Order*, (2^{nd} ed),Dover, 1955.
4. J. B. Fraleigh, *A First Course in Abstract Algebra*, (3^{rd} ed), Narosa, 2003.
5. J. A. Gallian, *Contemporary Abstract Algebra*, (4^{th} ed), Narosa, 1998.
6. B. Hartley and T. O. Hawkes, *Rings, Modules and Linear Algebra*, Chapman and Hall (1^{st} ed), 1970.
7. I. N. Herstein, *Topics in Algebra*, (2^{nd} ed),Vikas Publishing House, 1976.
8. T. W. Hungerford, Algebra, Springer, 1974.
9. I. S. Luthar and I. B. S. Passi, *Algebra (vol. 2), Rings*, Narosa Publishing House, 1999.
10. D. S. Malik, J. N. Mordeson and M. K. Sen, *Fundamentals of Abstract Algebra*, McGraw-Hill, 1997.
11. C. Musili, *Rings and Modules*, (2^{nd} revised ed), Narosa, 1994.
12. S. Singh and Q. Zameeruddin, *Modern Algebra*, (7^{th} ed),Vikas Publishing House, 1993.

Core Course-II

MAT-MC3: Topology

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: It is a thorough course on point-set topology, aimed to enable the reader for further advanced courses in topology such as Di erential and Algebraic Topology.

Unit-I

Topological spaces, bases for a topology, linear order, linear continuum, immediate successor/predecessor,

MAT-MC4: Real Analysis

Credits: 4

Essential Textbooks:

(A) W. Rudin, *Principles of Mathematical Analysis (3rd ed),* McGraw-Hill,1976.

(B) N. L. Carothers, *Real Analysis,* Cambridge University Press, 2000.

Further Readings:

1. T. Apostol, *Mathematical Analysis (2^{nd} ed)*, Narosa, 1973.
2. R. G. Bartle, D. R. Sherbert, *Introduction to Real Analysis (3^{rd} ed),* John Wiley & Sons, 2002.
3. R. R. Goldberg, *Methods of Real Analysis,* Oxford and IHB Publishing Company, 1970.
4. S. C. Malik and S. Arora, *Mathematical Analysis (3^{rd} ed),* New Age International, 2008.
5. M. O' Searcoid, *Metric Spaces,* Springer, 2007.
6. S. Shirali and H. L. Vasudeva, *Metric Spaces,* Springer, 2006.
7. E. C. Titchmarsh, *The Theory of functions (2^{nd} ed),* Oxford University Press, 1961.

Core Course-III

MAT-MC5: Advanced Complex Analysis

Credits: 4

Contact hours: 60 7 hrs/per week (including Tutorials)
Max. Marks: 100 (Including Internal Assessment-20) Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: To study the fundamentals analytic functions, Cauchy's theorem, geometry of conformal transformations and analytic continuation.

Unit-I

The Taylor Series Theorem, zeros of analytic functions, Identity Theorem.

Chains and cycles, simply connected regions, homology version of Cauchy's theorem, Laurent series, classi cation of singularities, isolated singularity at in nity.

Unit-II

Cauchy residue theorem and real integrals using contour integration.

The argument principle and its applications, open mapping theorem, maximum modulus principle, Rouche's theorem, Hurwitz's theorem, Schwarz's lemmagularities, isola4(w)(agul0(1(theorem,)-492(Lauren02(I)]TJ/F8 9.962

Essential Textbooks:

(A) L. V. Ahlfors, *Complex Analysis,* Mc. Graw Hill, 1988.

(B) W. Tutschke, H. L. Vasudeva, *An Introduction to Complex Analysis: Classical and Modern Approaches,* Chapman & Hall/CRC, 2005.

Further Readings:

1. J. Bak, D. J. Newman, *Complex Analysis (2^{nd} ed),* Springer-Verlag, 1997.
2. J. W. Brown, R. V. Churchill, *Complex Variables and Applications (2^{nd} ed),* McGraw Hill, 2009.
3. J. B. Conway, *Functions of One Complex Variable,* Narosa, 2002.
4. T. W. Gamelin, *Complex Analysis,* Springer-Verlag, 2008.
5. L. Hahn, B. Epstein, *Classical Complex Analysis,* Jones and Bartlett, 2011.
6. H. S. Kasana, *Complex Variables: Theory and Applications (2^{nd} ed),* PHI, 2005.
7. S. Ponnusamy, *Foundations of Complex Analysis (2^{nd} ed),* Narosa, 2005.
8. D. Ullrich, *Complex Made Simple,* American Mathematical Society, 2008.

OR

MAT-MC6: Complex Analysis

Credits: 4

Contact hours: 60 | 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) | Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: To study the fundamentals of di erentiation and integration of complex functions; their applications and the properties of analytic functions.

Unit-I

The complex plane, extended complex plane, stereographic projection, exponential, trigonometric, argument, logarithm and power functions, connected sets, connected components, path connectedness.

Derivative of a complex function, Cauchy-Riemann equations, analytic functions, harmonic functions,

Further Readings:

1. J. Bak, D. J. Newman, *Complex Analysis (2nd ed),* Springer-Verlag, 1997.
2. J. W. Brown, R. V. Churchill, *Complex Variables and Applications (2nd ed),* McGraw Hill, 2009.
3. J. B. Conway, *Functions of One Complex Variable,* Narosa, 2002.
4. T. W. Gamelin, *Complex Analysis,* Springer-Verlag, 2008.
5. L. Hahn, B. Epstein, *Classical Complex Analysis,* Jones and Bartlett, 2011.
6. H. S. Kasana, *Complex Variables: Theory and Applications (2nd ed),* PHI, 2005.
7. S. Ponnusamy, *Foundations of Complex Analysis (2nd ed),* Narosa, 2005.
8. D. Ullrich, *Complex Made Simple,* American Mathematical Society, 2008.

Core Course-IV

MAT-MC7: Linear Programming

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
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Essential Textbooks:

(A) S. Chandra, Jayadeva and A. Mehra, *Numerical Optimization with Applications*, Narosa, 2009.

(B) G. Hadley, *Linear Programming*, Narosa (6^{th} ed), 1995.

Further Readings:

1. N. S. Kambo, *Mathematical Programming Techniques*

Core Course-V

MAT-MC8: Classical Mechanics

Credits: 4

Contact hours: 60 7 hrs/per week (including Tutorials)
Max. Marks: 100 (Including Internal Assessment-20) Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: The objective of this paper is to introduce the concept of variation of a functional and variational techniques. The Calculus of variation helps a lot to understand the Lagrangian and Hamiltonian equations for dynamical systems. Variational principles and their applications are introduced at large

Unit-I

Calculus of variations: Functional and their properties, Motivating problems of Calculus of variations, Shortest distance, Minimum surface of revolution, Brachistochrone problem, Isoperimetric problems, Geodesics, Fundamental lemma of Calculus of Variations, Euler's equation for one dependent function and its generalization to (i) n dependent functions, (ii) Higher order derivatives, Variational problems with moving boundaries, Variation under constraints, Variational methods of Rayleigh-Ritz and Galerkin.

Unit-II

Lagrangian Mechanics: Generalized coordinates, Constraints, Holonomic and non-holonomic systems, Scleronomic and Rheonomic systems, Generalized velocity, Generalized potential, Generalized force, D'Alembert's principle, Lagrange's equation, Velocity dependent Potentials and Dissipation function, Expression of Kinetic energy using generalized velocity, Non-uniqueness in the choice of Lagrangian.

Unit-III

Lagrangian Mechanics: Hamilton's principle, Principle of Least action, Derivation of Lagrange's equations from Hamilton's principle, Cyclic co-ordinates, Conjugate momentum, Conservation theorems. Hamiltonian Mechanics: Legendre's transformation, Hamilton's equations, Routhian, Poisson Bracket, Jacobi identity for Poisson bracket, Poission theorem.

Unit-IV

Further Readings:

1. M. Artin, *Algebra*, Prentice Hall of India, 1994.
2. N. Jacobson, *Basic Algebra-II*, Hindustan Publishing Corporation 1994.
3. R. Y. Sharp, *Steps in Commutative Algebra*, Cambridge University Press, 1990.
4. O. Zariski and P. Samuel, *Commutative Algebra*, (vol. 1 & 2), Springer 1975.

OR

Further Readings:

1. M. Artin, *Algebra*, Prentice Hall of India, 1994.
2. P. B. Bhattacharya, S.K. Jain and S.R. Nagpal, *Basic Abstract Algebra*, (2^{nd} ed),Cambridge University Press, 2002.
3. J.-P. Escofier, *Galois Theory*, Springer, 2001.
4. J. B. Fraleigh, *A First Course in Abstract Algebra*, (3^{rd} ed) Narosa, 2003.
5. J. A. Gallian, *Contemporary Abstract Algebra*, (4^{th} ed), Narosa, 1998.
6. J.B. Hartley and T. O. Hawkes,

Core Course-VII

MAT-MC11: Number Theory-I

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: The aim of this course is to teach the students about the basics of Elementary Number Theory starting with primes, congruences, quadratic residues, primitive roots, arithmetic functions. Apart from teaching the theory, stress will be on solving problems.

Unit-I

Divisibility, Greatest common divisor, Euclidean algorithm, The Fundamental theorem of arithmetic, Congruences, Residue classes and reduced residue classes, Chinese remainder theorem, Fermat's little theorem.

Unit-II

Wilson's theorem, Euler's theorem and its application to a cryptography, Arithmetic functions $(n); d(n); (n); (n);$ Mobius inversion formula, Greatest integer function.

Unit-III

Primitive roots and indices. Quadratic residues, Legendre symbol, Euler's criterion, Gauss lemma, Quadratic reciprocity law, Jacobi symbol.

Unit-IV

Representation of an integer as a sum of two and four squares. Diophantine equations $ax+by = c; x^2+y^2 = z^2;$ and $x^4 + y^4 = z^2:$ Binary quadratic forms and equivalence of quadratic Forms. Perfect numbers, Mersenne primes and Fermat numbers, Farey fractions.

Essential Textbook:

(A) D. M. Burton, *Elementary Number Theory* (6^{th} ed), Tata McGraw Hill, 2007.

Further Readings:

1. H. Davenport, *The Higher Arithmetic*, (7^{th} ed), Camb. Univ. Press, 1999.
2. G. H. Hardy and E. M. Wright, *An Introduction to Theory of Numbers*, (6^{th} ed), Oxford University Press, 2008.
3. I. Niven, H. S. Zuckerman and H. L. Montgomery, *An Introduction to the Theory of Numbers*, (5^{th} ed), John Wiley and Sons, 2004.

OR

Further Readings:

1. G. E. Andrews, *Number Theory*, Dover Books, 1995.
2. D. M. Burton, *Elementary Number Theory*, (6^{th} ed), Tata McGraw Hill, 2007.
3. G. H. Hardy and E. M. Wright, *An Introduction to Theory of Numbers,* (6^{th} ed), Oxford University Press, 2008.

Core Course-VIII

MAT-MC13: Lebesgue Integration

Credits: 4

Contact hours: 60 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) Time allowed: 3hrs.

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Further Readings:

1. G. de Barra, *Measure Theory and Integration (2^{nd} ed),* New Age Inter. Pub., 2013.
2. R. G. Bartle, *Elements of Integration,* John Wiley and Sons, 1966.
3. S. K. Berberian, *Measure and Integration,* AMS, 2013.
4. V. I. Bogachev, *Measure Theory,* (vol. 2), Springer, 2007.
5. N. L. Carothers, *Real Analysis,* Cambridge University Press, 2000.
6. S. B. Chae, *Lebesgue Integration (2^{nd} ed),* Springer, 1994.
7. C. S. Kubrusly, *Essentials of Measure Theory,* Springer, 2015.
8. C. S. Kubrusly, *Measure Theory: A First Course,* AP Elsevier, 2007.

Core Course-IX

Essential Textbooks:

(A) R. P. Agarwal, and Donal O'Regan,

Core Course-X

MAT MC15: Probability Theory and Random Processes

Credits: 4

Total Lectures: 60 | 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) | Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: This course delves into the core principles of probability, conditional probability and probability distributions and emphasizes the practical application of these concepts to random processes, Markov chains, and Markov processes.

Unit-I

Classical probability concept, sample space, events, axiomatic approach to probability, conditional probability, Bayes' theorem. Random variables (continuous and discrete), cumulative distribution function (cdf), probability mass function (pmf); probability density functions (pdf). Multivariate distributions, marginal and conditional distributions, stochastic independence.

Unit-II

Mathematical expectations, moments, moment generating function, product moments, conditional expectations. Distributions: discrete uniform, Bernoulli, binomial, geometric, negative binomial, hypergeometric, Poisson, continuous uniform, exponential, Erlang-k, gamma, beta, normal (Gaussian) distributions.

Unit-III

Random processes and Discrete-Time Markov Chains (DTMC): Basic de nitions, sojourn time, dependent and embedded Markov chains, one-step and higher transition probabilities, Chapman Kolmogorov equations, Bernoulli and Markov Bernoulli chains. Chain classi cation: Transient, positive recurrent, null recurrent, absorbing states. Higher transition probabilities, Markov chains with a denumerable number of states, aperiodic, ergodic, and periodic chains, irreducibility and reducible Markov chains.

Unit-IV

Potential, fundamental, and reachability matrices, mean time to absorption, absorption probabilities, random walk problems, stationary, limiting, steady-state distributions, reversibility and Kolmogorov's criterion. Continuous-Time Markov Chains (CTMC): Transition probabilities and rates, Chapman-Kolmogorov equations, embedded chain and state properties, transient, stationary, limiting and steady-state distributions and reversibility. Semi-Markov processes, renewal processes, renewal reward processes and alternating renewal processes.

Scope: Relevant sections of chapters 1 to 9 of (A) and chapters 1 to 7 of (B).

Essential Textbook:

(A) W. J. Stewart, *Probability, Markov chains, queues, and simulation: the mathematical basis of performance modelling,* Princeton University Press, 2009.

(B) Irwin Miller, Marylees Miller *John E. Freund's Mathematical Statistics: With Applications, (*8^{th} *Ed.),* Pearson Education, 2021.

Further Readings:

1. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, *Introduction to Mathematical Statistics,* Pearson New International Edition, Asia, 2007.
2. J. Medhi, *Stochastic Processes,* 3^{rd} *Edition,* New Age International, 2009.
3. S. M. Ross, *Stochastic Processes,* 2^{nd} *Edition,* Wiley (WSE Edition), 1996.
4. Ramon van Handel, *Probability and Random Processes*. Lecture Notes, Princeton University, 2016, http://web.math.princeton.edu/ rvan/ORF309.pdf
5. G. R. Grimmett and D. R.Stirzaker, *Probability and Random Processes,* 3^{rd} *Edition,* Oxford University Press, 2001.
6. P Ramesh Babu, *Probability Theory and Random Processes,* McGraw Hill Education (India), New Delhi, 2015.
7. Ali Grami,

Semester-III
Core Course-XI
MAT-MC16: Non-Commutative Ring Theory

Credits: 4

Essential Textbook:

(A) I. N. Herstein, *Non-Commutative Rings,* The Mathematical Association of America, 1968.

(B) C. P. Milies and S. Sehgal, *An introduction to group rings. Algebra and Applications,* Kluwer Academic Publishers, Dordrecht, 2002.

Further Readings:

1. P.M. Cohn, *Further Algebra and Applications, Springer,* 2003.
2. T. Y. Lam, *A First Course in Non-commutative Rings,* Springer-Verlag, 1991.
3.

MAT-MC17: Linear Algebra and Commutative Algebra { I

Credits: 4

Contact hours: 60 7 hrs/per week (including Tutorials)
Max. Marks: 100 (Including Internal Assessment-20) Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective::The objectives of this course is to develop a strong foundation in linear Algebra that provide a basis for advanced studies not only in Mathematics but also in other branches like engineering, physics and computers etc. Particular attention to canonical forms of linear maps, matrices, bilinear forms and quadratic forms is given. The aim is to develop necessary prerequisites for MAT-MC22.

Unit-I

Linear Algebra: Eigenvalues and eigenvectors, Eigenspaces and similarity, Representation by a diagonal matrix; Linear functionals, Real quadratic forms, Orthogonal matrices, Reduction of real quadratic forms, Classi cation of real quadratic forms.

Unit-II

Bilinear forms, Symmetric bilinear forms, Hermitian forms; Inner product spaces, Norms and distances, Orthonormal bases, Orthogonal complements, Isometries, Normal matrices, Normal linear operators.

Unit-III

Projections and direct sums, Spectral decompositions, Minimal polynomials and spectral decompositions, Nilpotent transformations, The Jordan canonical form.

Unit-IV

Commutative Algebra: Rings and ideals, Modules, Tensor products of modules.

Essential Textbooks:

(A) J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory*, Academic Press, 1995.

(B) I. G. MacDonald and M. F. Atiyah, *Introduction to Commutative Algebra*, Levant Books, 2007.

Further Readings:

1. S. H. Friedberg, A.J. Insel and L.E. Spence, *Linear Algebra*

Core Course-XII

MAT-MC18: General Measure Theory

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: To study measure in an abstract setting, after having studied Lebesgue measure on real line. The general L^p-spaces, complex measure, Fubini's theorem, Fourier transformations in a general setting are to be studied in this course.

Unit-I

-spaces,ter

Abstract integration, the concept of measurability, simple functions, elementary properties of measures, integration of positive functions, integration of complex functions, the role played by sets of measure zero.

Unit-II

Positive Borel measures: vector spaces, upper/lower semi continuous functions, partition of unity theorem, Riesz representation theorem for $C_c(X)$ (statement only). Regularity properties of Borel measures, Lusin's theorem, Vitali CaratheodiOrf 6.573heorem,L

Further Readings:

1. G. de Barra, *Measure Theory and Integration* (2^{nd} *ed),* New Age Inter. Pub., 2013.
2. R. G. Bartle, *Elements of Integration,* John Wiley and Sons, 1966.
3. S. K. Berberian, *Fundamentals of Real Analysis,* Springer, 2012.
4. S. K. Berberian, *Measure and Integration,* AMS, 2013.
5. V. I. Bogachev, *Measure Theory,* (vol. 2), Springer, 2007.
6. S. B. Chae, *Lebesgue Integration* (2^{nd} *ed),* Springer, 1994.
7. C. S. Kubrusly, *Essentials of Measure Theory,* Springer, 2015.
8. H. L. Royden, *Real Analysis (3rd ed.),* Pearson Prentice Hall, 2007.

OR

MAT-MC19: Topology

Credits: 4

Contact hours: 60 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) Time allowed: 3hrs.

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Further Readings:

1. M. A. Armstrong, *Basic Topology,* Springer, 1983.
2. J. Dugundji, *Topology,* Allyn and Bacon, 1978.
3. T. W. Gamelin, R. E. Greene,

Scope: Relevant sections of the essential textbooks.

Essential Textbooks:

(A) L. C. IVANS, *Partial Di erential Equations,* American Mathematical Society, 2002.

(B) P. PRASAD and R. RAVINDRAN, *Partial Di erential Equations,* New Age International Publishers, 2015.

(C) K. SANKARA RAO, *Introduction to Partial Di erential Equations,* PHI Learning Private Limited, 2013.

(D) A. K. NANDAKUMARAN and P.S. DATTI, *Partial Di erential Equations: Classical Theory with Modern Touch,* Cambridge University Press, 2020.

Further Readings:

1. F. JOHN, *Partial Di erential Equations (*4^{th} *ed),* Springer-Verlag, 2009.
2. A. TVEITO and R. WINTER,

Semester-IV
Core Course-XIV
MAT-MC21: Representation Theory of Finite Groups

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: The representation theory of nite groups solidi es one's knowledge of group theory. The theory has been a key ingredient in the classi cation of nite simple groups. It goes back to F. Klein who considered the possibility of representing a given abstract group by a group of linear transformations(matrices) preserving the group's structure. Leading mathematicians such as G. Frobenius, I.Schur, W. Burnside and H. Maschke followed and developed the idea further. Essentially, it is designed to give an explicit answer to the question"What are the di erent ways (homomorphisms) a nite group G can occur as a group of invertible matrices over a particular eld F?". The link between group representations over a eld F and modules is obtained using the concept of a group ring F[G], thus an essential step is the systematic study and classi cation of group rings (the so-called semisimple algebras) which behave like products of matrix rings. Therefore, the story of the representation theory of a group is the theory of all F[G]-modules, viz modules over the group ring of G over F. The ultimate goal of this course is to teach students how to construct complex representations for popular groups as well as their character tables which serve as invariants for group rings. In addition to the applications to physical symmetry, the theory leads to signi cant applications to the structure theory of nite groups.

Unit-I

The Group Algebra FG, Group representations, FG-modules, FG-submodules and reducibility, Maschke's Theorem, Semisimplicity of Group Algebras, Schur's Lemma, Irreducible modules and the group algebra.

Unit-II

Conjugacy classes, Characters, Inner product of characters, The number of irreducible complex characters, Character tables and orthogonality relations.

Unit-III

Normal subgroups and lifted characters, Character tables of S3, S4, A4, D2n Tensor products, Restriction of characters, Constituents of restricted character, Induced modules and characters.

Unit-IV

Integrity of Complex Characters, Burnside's -Theorem, Frobenius reciprocity theorems, Conjugate representations, Cli ord's decomposition theorem, Mackey's irreducibility criteria.

Essential Textbooks:

(A) J. Gordan and L. Martin, *Representations and Group Characters (2nd ed),* Cambridge University Press, 2001.

(B) I. M. Issacs, *Character theory of nite groups,* AMS Chelsea Publishing, 2006.

Further Readings:

1. C. P. Milies and S. Sehgal, *An Introduction to Group Rings - Algebra and Applications,* Academic Publishers, 2002.
2. C. Musili, *Representations of Finite Groups,* Hindustan Book Agency, 1993.
3. J. P. Serre, *Linear Representations of Finite Groups,* Springer-Verlag, 1977.

OR

MAT-MC22: Commutative Algebra II

Credits: 4

Contact hours: 60 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: Commutative Algebra is the study of commutative rings, their modules and ideals. This theory has developed over the last 150 years not just as an area of algebra considered for its own sake, but as a tool in the study of two enormously important branches of mathematics: algebraic geometry and algebraic number theory. This course will give students a background in commutative algebra.

Unit-I

Rings and Modules of fractions, Local properties, Extended and contracted ideals in ring of fractions, Primary Decomposition.

Unit-II

Integral dependence, The going up theorem, Integrally closed domains, The going down theorem, valuations rings, Hilbert's Nullstellensatz theorem.

Unit-III

Chain conditions on modules and rings, Noetherian and Artinian modules, Modules with nite composition length, Noetherian rings and Hilbert's Basis Theorem, Primary decomposition in Noetherian rings and Noether-Lasker Theorem.

Unit-IV

Artinian rings, Maximality of prime ideals of Artinian rings, Artinian Rings are Noetherian, Conditions on Noetherian rings which make them Artinian. Local Artinian rings and Structure theorem of Artinian rings, Discrete valuation rings, Dedekind domains, Fractional ideals.

Essential Textbook:

(A) M. F. Atiyah and I. G. MacDonald, *Introduction to Commutative Algebra,* Levant Books, 2007.

Further Readings:

1. M. Artin, *Algebra,* Prentice Hall of India, 1994.

2. N. Jacobson, *Basic Algebra-II,* Hindustan Publishing Corporation 1994.

3. H. Matsumura, *Commutative Ring Theory,* Cambridge University Press 1989.

4. R. Y. Sharp, *Steps in Commutative Algebra,* Cambridge University Press, 1990.

Core Course-XV
MAT-MC23: Functional Analysis

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: The objective of this course is to study the basics of Banach and Hilbert spaces. It also includes various types of operators on Hilbert and Banach spaces.

Unit-I

Normed Spaces with examples of function spaces $L^p[a;b]; C[a;b]$ and $C^1[a;b];$ Sequence Spaces $l^p; c; c_0; c_{00};$ Quotient spaces, Banach Spaces, equivalence of norms, Riesz lemma, characterizations of nite dimensional normed spaces, Schauder basis and separabiity, Baire Category theorem and its applications.

Unit-II

Hahn Banach Theorem, the space of bounded operators, Uniform Boundedness Principle (Banach Steinhaus Theorem), Resonance Theorem, Open Mapping Theorem, Closed Graph Theorem, Two Norm Theorem, Bounded Inverse Theorem, Projections on Banach Spaces, Duals of Sequence Spaces and their Re exivity, Weak convergence in Banach spaces.

Unit-III

Geometry of Hilbert spaces: Inner product spaces with examples from sequence spaces l^p and functional spaces $L^p;$ Pythagorean identity, Bessel's Inequality, Riesz-Fisher Theorem, orthonormal sets, Parseval's formula, approximation and optimization, orthogonal complements, Projections and Riesz Representation Theorem.

Unit-IV

Weak convergence in Hilbert spaces. Bounded Operators on Hilbert spaces: Bounded operators and adjoints, computation of adjoint in separable Hilbert spaces, self-adjoint and positive operators, normal and unitary operators.

Scope:

Essential Textbook:

(A) B. V. Limaye, *Functional Analysis (3rd ed),* New Age International Publishers, 2017.

Further Readings:

1. S. K. Berberian, *Introduction to Hilbert Space (2nd ed),* American Mathematical Society, 1996.
2. R. Bhatia, *Notes on Functional Analysis,* Hindustan Book Agency, 2009.
3. A. Bowers, N. J. Kalton, *An Introductory Course in Functional Analysis,* Springer, 2014.
4. A. Bressan, *Lecture Notes on Functional Analysis- with Applications to Linear Partial Di erential Equations,* American Mathematical Society, 2012.
5. E. Kreyszig, *Introductory Functional Analysis with Applications,* Wiley, 1978.
6. B. MacCluer, *Elementary Functional Analysis,* Springer-Verlag, 2009.
7. W. Rudin, *Real and Complex Analysis (3rd ed),* McGraw-Hill, 2017.
8. B. P. Rynne, Martin A. Youngson, *Linear Functional Analysis,* Springer, 2008.
9. M. Schechter, *Principles of Functional Analysis,* American Mathematical Society, 2002.

MAT-MDSE1: Computational Techniques{I (Theory)

Credits: 4

Total Lectures: 40 4 hrs/per week (including Tutorials)

Max. Marks: 80 (Including Internal Assessment-20) Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 12 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: This course is designed to provide the knowledge of computer programming in FORTRTAN-90/95. The course will facilitate the students to write a source program to compute the numerical solutions of the mathematical problems, which arise in di erent areas of engineering, physical, biological and social sciences. The purpose of Numerical methods for polynomial equations, Curve tting, Numerical di erentiation and integration will help in strengthening their computational skill.

Unit-I

Introduction to FORTRAN, Evolution of FORTRAN 90, Simple FORTRAN 90 programs, Numeric constants and variables, Arithmetic expressions, Input-output statements, Conditional statements.

Unit-II

Implementing Loops in programs, Logical expressions and more control statements, Function and subroutines, De ning and manipulating arrays, Elementary Format speci cations

Unit-III

Solution of nonlinear equations: Bisection, Secant, Regula-Falsi, Newton-Raphson methods and their convergence,

MAT-MDSE1:Computational Techniques{I (Practical)

Total Practicals: 20 — 3 hrs/per week

Max. Marks: 20 — Time allowed: 3hrs.

Writing programs in FORTRAN 90/95 for the problems based on the methods studied in the theory course and running them on PC. Teacher in charge will decide the nal topics of the assignments to cover from the following topics:

1. Numeric constants and variables, Arithmetic expressions,
2. Input-output statements, Conditional statements,
3. Loops in programs,
4. Logical expressions,
5. Control statements,
6. Function and subroutines
7. Arrays
8. Bisection-Method and their convergence
9. Newton-Raphson method and their convergence
10. Muller Method for complex roots
11. Trapeziodal
12. Simpson's 1/3 and 3/8 rules.
13. Boole's rule.

Essential Textbooks:

(A) V. Rajaraman, *Computer Programming in FORTRAN 90 and 95,* PHI Learning Pvt. Ltd., 1997.

(B) S. S. Shastry, *Introductory methods of numerical analysis,* PHI, 2012.

Further Readings:

1. Ed. Akin, *Object-oriented programming via Fortran 90/95,* Cambridge University Press, 2003.
2. S. K. Bose, *Numeric Computing in Fortran,* Alpha Science International, 2009.
3. C. F. Gerald and P. O. Wheatley, *Applied numerical analysis,* Addison-Wesley Publishing Co., 1989.
4. R. S. Gupta, *Elements of Numerical Analysis,* Cambridge University Press, 2015.
5. F. B. Hildebrand, *Introduction to Numerical Analysis,* Courier Corporation, 1987.
6. M. K. Jain, R. K. S. Iyengar and R. K. Jain, *Numerical methods: Problems and solutions,* New Age International, 2007.
7. M. Metcalf and J. K. Reid, *Fortran 90/95 Explained,* Oxford University Press, 1999.
8. M. Metcalf, J. K. Reid and M. Cohen *Modern Fortran Explained,* Oxford University Press, 2011.

MAT-MDSE2: Algebraic Number Theory-I

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: Mathematicians long back realized that the role and importance of rings bigger than the ring of integers in study of problems of number theory is crucial. This led to a new subject Algebraic Number Theory. In this course students will learn the basics of the subject.

Unit-I

Motivation from Fermat's Last Theorem, Eliptic Curves, Classi cation of primitive Pythagorean triples, Fermat's Theorem on sum of two squares, Number elds and Number rings, Norms, and Traces, Number Rings of quadratic and cyclotomic number elds.

Unit-II

Discriminant, Number rings and their ideals as free abelian groups, Integral basis, Calculations of integral basis in

MAT-MDSE3: Algebraic Coding Theory-I

Credits: 4

MAT-MDSE5: Fluid Mechanics-I

Pre-requisites: Statics, Dynamics at undergraduate level

Credits: 4

Contact hours: 60 — **7 hrs/per week (including Tutorials)**

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: The objective of this course is to introduce the students to the fundamentals of the study of uid motion and to the analytical approach to the uid mechanics problems. The students will learn to develop

Unit-IV

Some solvable problems in Steady, Incompressible, Viscous ow: Plane Couette ow, Poiseuille ows, Circular Couette ow, Flow through a pipe of circular cross section. Steady Flow under constant pressure gradient through tubes of uniform cross- section: Uniqueness theorem, Flow through pipe of cross-section in the form of circle, ellipse and equilateral triangle.

Essential Textbooks:

(A) F. Chorlton, *Text Book of Fluid Dynamics,* CBS Publishers, Indian Edition, 2004.

(B) M. E.O. Neill and F. Chorlton, *Ideal and Incompressible Fluid Dynamics,* John Wiley & Sons, 1986.

Further Readings:

1. G. K. Batchelor, *An Introduction to Fluid Mechanics,* Cambridge University Press, 1967.
2. W. H. Besant and A. S. Ramsey, *A Treatise on Hydromechanics, Part-II,* CBS Publishers, 1988.
3. P. Kundu and I. Cohen, *Fluid Mechanics,* Harcourt (India) Pvt.Ltd., 2003.
4. L. D. Landau & E. N. Lipschitz, *Fluid Mechanics (2nd ed) vol. 6 (Course of Th. Phy.),* Pergamon, 1987.
5. S. W. Yuan, *Foundations of Fluid Mechanics,* PHI, 1976.

Essential Textbooks:

(A) M. S. Bazaraa and C.M. Shetty, *Nonlinear Programming, Theory & Algorithms* (2^{nd} *ed),* Wiley, 2004.

(B) S. M. Sinha, *Mathematical Programming, Theory and Methods,* Elsevier, 2006.

Further Readings:

1. N. S. Kambo, *Mathematical Programming Techniques,* A liated East-West Press, 2005.
2. O. L. Mangasarian, *Nonlinear Programming* (1^{st} *ed),* McGraw Hill, 1969.
3. K. Swarup, P. K. Gupta and Man Mohan, *Operations Research* (9^{th} *ed),* Sultan Chand & Sons, 2001.

MAT MDSE7: Mathematical Statistics

Credits: 4

Total Lectures: 60 | 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) | Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: This course covers the fundamental concepts of statistical inference, including limit theorems, point and interval estimation, hypothesis testing, and regression and correlation analysis. The objective of the syllabus is to provide students with the knowledge and skills necessary to make informed decisions based on statistical analysis.

Unit-I

Limit Theorems: Markov inequality, Chebychevp to

(B) Robert V. Hogg, Joseph W. McKean and Allen T. Craig, *Introduction to Mathematical Statistics,* Pearson New International Edition, Asia, 2007.

Further Readings:

1.

MAT-MDSE8: Mechanics of Solids { I

Pre-requisites: Undergraduate courses in Statics and Dynamics

Credits: 4

Contact hours: 60 | 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) | Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: This course introduces the basics of continuum mechanics and mathematical theory of elasticity. The topics are the foundations to understand basic and applied problems in the area of waves and vibrations in elastic solids.

Unit-I

Su x notation: Range and Summation conventions, Free and dummy su xes, Results in vector algebra and matrix algebra, The symbols $_{ij}$ and $_{ijk}$

Essential Textbooks:

(A) D. S. Chandrasekharaiah and L. Debnath, *Continuum Mechanics,* Academic Press, 1994.

(B) I. S. Sokolnikoff, *Mathematical Theory of Elasticity,* McGraw Hill, 1977.

Further Readings:

1. Y. C. Fung, *Foundations of Solid Mechanics,* Prentice Hall, 1965.
2. A. E. H. Love, *A Treatise on the Mathematical Theory of Elasticity.* Dover Publications, 2003.
3. S. Narayan, *Text Book of Cartesian Tensor,* S. Chand & Co., 1950.

MAT-MDSE9: Numerical Methods for Di erential Equations (Theory)

MAT-MDSE9: Numerical Methods for Di erential Equations { I (Theory)

Pre-requisites: MC14: Ordinary Di erential equations

Credits: 4

Total Lectures: 40 **4 hrs/per week (including Tutorials)**

Max. Marks: 80 (Including Internal Assessment-20) Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: The aim of this course is to teach the basics of MATLAB package. At the end of the course, the students will be able to do programming in MATLAB and understand the basic concepts in Numerical Analysis of di erential equations.

Unit-I

Basics of MATLAB: MATLAB as a calculator, De ning Variables, Display format, Saving the variables stored in memory, Prede ned variable, Complex numbers, Vectors and Matrices. Control Flow: If-end, If-else-end, Elseif, Switch-case, For loops: Single for loops, Nested for loops, Special cases of the for loop, While loops. Functions: General Structure of function, Scope of variables, Passing variable, The Return statement, Nargin and nargout, Recursive functions. Plotting: Basic two-dimensional plots, Line styles, Markers, Colors, Plot Color, Plotting grid, Axis command, Placing text on a plot, Modifying text with Tex commands.

Unit-II

Polynomial splines and Generalizations: Cubic splines, De nition of cubic and m splines, Derivation of B splines, Quintic spline interpolate, Splines and ordinary di erential equations, Error analysis. The method of collocation: Introduction, A simple special case, existence via matrix analysis, Green's functions, Collocation existence via green's functions, Error analysis via Green's function, Collocation and partial di erential equations, Orthogonal collocation, A connection between Collocation and Galerkin methods.

Unit-III

Basic steps of nite element analysis: Model boundary value problem, Descretization of the domain, Derivation of element equation, Connectivity of elements, Imposition of boundary conditions, Solution of equations, Post processing of the solution, Radially symmetric problems. Finite Element Error Analysis: Approximation Errors, Various Measure of Errors, Convergence of solutions, Accuracy of the solution.

Unit-IV

Finite Element Analysis of two Dimensional Problems: The model equation, Finite element discretization, Weak form of the problem, Finite element formulation, Interpolation functions, Linear triangular element, Linear rectangular element, Evaluation of element matrices and vectors, Assembly of element equations, Post processing, Axisymmetric problems, Finite element formulation for Poisson' problem.

MAT-MDSE9: Numerical Methods for Di erential Equations (Practical)

Total Lectures: 20 3 hrs/per week (including Tutorials)

Max. Marks: 20 Time allowed: 3hrs.

Writing programs in Matlab for the following problems and run them on PC.

1. Write a program in Matlab to solve a polynomial equation.
2. Write a program in Matlab to nd $C(n; r)$:
3. Write a program in Matlab to write a tridiagonal matrix.
4. Write a program in Matlab to solve 51

$$y' = y^2 - y^3; \quad y(0) = p; \quad 0 \le t \le \frac{2}{p}$$

Here, $y(t)$ represents the radius of the ball. The y^2 and y^3 terms come from the surface area and volume. The critical parameter is the initial radius p. Write a program in Matlab to find the numerical solution.

11. Consider the initial value

$$x' = -(1 + t + t^2) - (2t - 1)x - x^2; \quad 0 \le t \le 3; \quad x(0) = -1/2.$$

The exact solution is given by $x(t) = -t - \frac{1}{e^t+1}$. Write a Program in Matlab to find the numerical solution and compare it with the exact solution.

12. A mass-spring system can be modeled via the following second-order ODE

$$Y'' + cy' + w^2 y = g(t); \quad y(0) = 1; \quad y'(0) = 0.$$

Write a program in Matlab to find the numerical solution for the particular set of conditions $c = 5; w = 2$ and $g(t) = sin(t)$

13. Write a program in Matlab to evaluate shape functions for

a) Three node element.

b) Four node element.

14. Write a program in Matlab to find the numerical solution the reaction-diffusion problem defined on $(0;1)$ with the homogeneous boundary conditions using method of collocation.

15. Write a program in Matlab to find the numerical solution the convection-diffusion problem defined on $(0;1)$ with the homogeneous boundary conditions using method of collocation.

16. Write a program in Matlab to find the numerical solution of the following problem

$$y'' = -2; \quad 0 < x < 1 \quad ; \quad y(0) = 0; \quad y'(0) = 0$$

using finite element method.

17. Write a program in Matlab to find the numerical solution of the Poisson equation defined on a square region with Dirichlet boundary condition using finite element method.

Practical shall be conducted by the department as per the following distribution of marks. Writing program in Matlab and running it on PC=10 Marks Practical record=5 Marks Viva-Voice=5 Marks

Further Readings:

1. M. E. Herniter, *Programming in Matlab,* CL-Engineering, 2000.
2. D. J. Higham and N. J. Higham, *MATLAB Guide, (2^{nd} ed),* SIAM 2005.
3. C. B. Moler, *Numerical Computing with MATLAB,* SIAM, Philadephia, 2004.
4. P M Prenter, *Splines and Variational Methods, illustrated,* Dover Publications, 2008.
5. J. N. Reddy, *An Introduction to the Finite Element Method (2^{nd} ed),* TATA McGraw-Hill, 2003.
6. G. Strang and G. J. Fix, *An Analysis of the Finite Element Method (2^{nd} ed),* Cambridge Press, 2008.
7. E. G. Thompson, *Introduction to the Finite Element Method,* John Wiley & Sons, Inc., 2005.

MAT-MDSE10: Computational Techniques{II (Theory)

Credits: 4

Total Lectures: 40 4 hrs/per week (including Tutorials)

Max. Marks: 80 (Including Internal Assessment-20) Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 12 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: This course is designed to provide the knowledge of computer programming in C. The students will be able to write source program to compute the numerical solutions of the mathematical problems of di erent areas of sciences. The purpose of Numerical methods for simultaneous equations and IVP/BVP will help in practicing their computational skill.

Unit-I

Historical Development of C, Character set, Constants, Variables, C- key words, Instructions, Hierarchy of operators, Operators, Simple C-programs, Control, Structures. If, If-else, Nested if-else, unconditional goto, Switch structures.

Unit-II

Logical and Conditional operators, While, Do-while and for loops, Break and continue statements, Arrays, Functions, Library functions, Function recursion, Pointers, Pre-processor, Structures, File

Unit-III

Method of solving simultaneous equations: Gauss elimination, Gauss { Jordan, LU Decomposition, Gauss-Jacobi and Gauss-Seidel methods, Numerov method, Sensitivity of solution of linear equations, Linear and non-linear curve tting, Curve tting by sum of exponential.

Unit-IV

Solution of IVP: Taylor's, Picard method, Euler, Euler-Modi ed, Runge-Kutta methods , Numerical method its order and Stability, Predictor-Corrector method: Milne's and Adam-Bashforth methods, Finite Di erence and Shooting methods for BVP, FDM for Laplace and heat equations. Cubic spline, Finite Element method.

MAT-MDSE10: Computational Techniques{II (Practical)

Total Practicals: 20 | 3 hrs/per week

Max. Marks: 20 | Time allowed: 3hrs.

Writing programs in C for the problems based on the methods studied in the theory course and running them on PC. Teacher in charge will decide the nal topics of the assignments to cover from the following topics:

1. Hierarchy of operators
2. Control Structure
3. If, If else, nested if-else
4. Switch structures
5. Logical operators

MAT-MDSE11: Algebraic Number Theory II

Pre-requisites: MDSE2: Algebraic Number Theory-I

Credits: 4

Contact hours: 60 | **7 hrs/per week (including Tutorials)**

Max. Marks: 100 (Including Internal Assessment-20) | Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: Mathematicians long back realized that the role and importance of rings bigger than the ring of integers in study of problems of number theory is crucial. This led to a new subject Algebraic Number Theory. In this course the students, who have already taken the Algebraic Number Theory I course, will be exposed to some advanced topics of the subject.

Unit-I

Lattices, Fundamental Parallelotope and their properties, Viewing number rings as lattices, Minkowski's bound, Calculations of class numbers of Q(d1/2) for d = -1, -2, -3, -7, -11, -19, -43, -67, -163, -5, -6, 10. Calculation of class numbers of some cubic and biquadratic number elds, Examples of PIDs that are not Euclidean domains.

Unit-II

Discrete subgroups of Rn and their characterization, Minkowski's Convex Body Theorem, Dirichlet's Unit Theorem, Calculation of unit-groups of quadratic number elds and torsion units of cyclotomic number eld.

Unit-III

Splitting of prime ideals in extensions, Rami cation Indices, Inertial degrees, Their transitivity and other properties, Equality of rami cation indices and inertial degrees in normal extensions, Decomposition of rational primes in quadratic and cyclotomic number elds.

Unit-IV

Relative Trace, Norm and Discriminant, Dedekind's Theorem of rami cation of primes, Di erent Ideal and rami cation of prime ideals dividing it.

Essential Textbook:

(A) P. Ribenboim, *Classical Theory of Algebraic Numbers,* Springer-Verlag, 2001.

Further Readings:

1. S. Alaca and K. S. Williams, *Introductory Algebraic Number Theory,* Cambridge University Press 2004.
2. D. A. Marcus, *Number Fields,* Springer-Verlag, 1977.
3. R. A. Mollin, *Algebraic Number theory,* Chapman & Hall/CRC, 2011.
4. P. Samuel, *Algebraic Theory of Numbers,* Dover Publications, 1970.
5. I. Stewart and D. Tall, *Algebraic Number theory (2^{nd} ed),* Chapman & Hall, 1907.

MAT-MDSE12: Algebraic Coding Theory-II

Pre-requisites: MDSE3: Algebraic Coding Theory-I

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt five, by selecting at least one question from each unit.*

Objective: Cyclic codes play a significant role in the theory of error correcting codes. They can be efficiently encoded using shift registers, which explains their preferred role in engineering. The objectives of this course is to teach the algebraic structure of cyclic codes over fields and rings, their properties and some special cyclic codes.

Unit-I

Review of finite fields, Factorization of over finite fields. Cyclic codes, Decoding of cyclic codes, Idempotents and multipliers, Zeros of a cyclic code, Decoding of cyclic codes, Minimal cyclic codes.

Unit-II

BCH codes, Quadratic Residue codes, Duadic codes, Orthogonality of Duadic codes, Weights in Duadic codes.

Unit-III

Reed-Soloman codes, Generalized Reed Soloman codes. Codes over Z4.

Unit-IV

Cyclic codes over rings specially over Z4. Generating polynomials and generating idempotents of cyclic codes over Z4. Quadratic residue codes over Z4.

Essential Textbooks:

(A) W. C. Huffman and V. Pless,

MAT-MDSE13: Fluid Mechanics-II

Pre-requisites: MAT-MDSE5 Fluid Mechanics-I

Credits: 4

Contact hours: 60 — **7 hrs/per week (including Tutorials)**

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: This course is in continuation to the course MAT-MDSE5: Fluid Mechanics-I. This course is designed to make the students learn more advanced topics in the subject.

Unit-I

Essential Textbooks:

(A) F. Chorlton, *Text Book of Fluid Dynamics,* CBS Publishers, Indian Edition, 2004.

(B) M. E.O. Neill and F. Chorlton, *Ideal and Incompressible Fluid Dynamics,* John Wiley & Sons, 1986.

Further Readings:

1. G. K. Batchelor, *An Introduction to Fluid Mechanics,* Cambridge University Press, 1967.
2. W. H. Besant and A. S. Ramsey, *A Treatise on Hydromechanics, Part-II,* CBS Publishers, 1988.
3. P. Kundu and I. Cohen, *Fluid Mechanics,* Harcourt (India) Pvt.Ltd., 2003.
4. L. D. Landau & E. N. Lipschitz, *Fluid Mechanics* (2^{nd} *ed) vol. 6 (Course of Th. Phy.),* Pergamon, 1987.
5. S. W. Yuan, *Foundations of Fluid Mechanics,* PHI, 1976.

MAT-MDSE14: Mechanics of Solids-II

Pre-requisites: MDSE8: Mechanics of Solids-I

Credits: 4

Contact hours: 60 | **7 hrs/per week (including Tutorials)**

Max. Marks: 100 (Including Internal Assessment-20) | Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: The course is in continuation with Mechanics of Solids-I and has been form with an objective giving the basics foundation of waves and vibrations in elastic solids. It is useful tool to understand the problems related to earthquake science and problems of waves in manufactured bodies.

Unit-I

Waves: De nition of wave and basic terminologies, Harmonic waves, Plane waves, Wave equation in 3-D, Superposition of waves, Progressive type wave solutions, Stationary type wave solution of wave equation in di erent coordinate systems, Equation of Telegraphy, D'Alembert's Solution of wave equation, Dispersion of waves and group velocity, Relation between phase and group velocity.

Unit-II

Equations of Elasticity: Hooke's law and Generalized Hooke's Law, Strain energy function and its connection with Hooke's Law, Homogeneous isotropic medium. Elasticity moduli for Isotropic media. Simple tension, Pure shear, Hydrostatic pressure, Beltrami-Michell compatibility equations. Uniqueness of solution.

Unit-III

Extension of beams by longitudinal forces, Beam stretched by its own weight, Helmholtz Decomposition of vector, Equation of equilibrium, Dynamical equations for an isotropic elastic solid. Waves of dilatation and distortion, Reduction of equation of motion to wave equation, P and S waves, Polarization of S wave.

Unit-IV

Condition of existence and Frequency equation of Rayleigh waves, Love waves and Torsional waves. Particle motion of Rayleigh waves. Snell's law of re ection and refraction, Re ection of plane waves (P/SV and SH-waves) from free surface of an elastic half-space, Re ection and transmission at plane interface of two di erent elastic solids, Partition of energy at the interface.

Essential Textbooks:

(A) I. S. Sokolnikoff, *Mathematical Theory of Elasticity,* Tata-McGraw Hill, 1956.

(B) P. K. Ghosh, *The Mathematics of Waves and Vibrations,* The Mac-Millan Company of India ltd., 1975.

(C) K. E. Bullen, *An Introduction to the Theory of Seismology (2nd ed),* Cambridge University Press, 1953.

Further Readings:

1. D. S. Chandrasekharaiah and L. Debnath, *Continuum Mechanics,* Academic Press, 1994.
2. C. A. Coulson and A. Jefferey, *Waves, Longman,* 1977.
3. Y. C. Fung, *Foundations of Solid Mechanics,* Prentice Hall, 1965.
4. A. E. H. Love, *A Treatise on the Mathematical Theory of Elasticity.* Dover Publications, 2003.

MAT-MDSE15: Partial Di erential Equations { II

Pre-requisites: MC20: Partial Di erential Equations { I

Credits: 4

Contact hours: 60 **7 hrs/per week (including Tutorials)**

Max. Marks: 100 (Including Internal Assessment-20) Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: The objective of this course is to enable the students to understand the concepts related to the solutions of partial di erential equations studied during MC20 using transform methods. Some well-known PDEs will be explored in this course.

Unit-I

Separation of variables, Similarity solutions: Exponential solutions, Solitons (Korteweg-de Vries eqution), Barenblatt's solution of porous medium equation. Converting Nonlinear PDE into linear PDE: Cole-Hopf transformation and solution of Burger's equation with viscosity, Hodograph transform. Oscillating solution of wave equation.

Unit-II

Fourier Transform method to solve PDE: De nition on L^1 and

Scope: Relevant sections of the essential textbooks.

Essential Textbooks:

(A) L. C. Ivans, *Partial Di erential Equations,* American Mathematical Society, 2002.

(B) A. K. Nandakumaran and P. S. Datti, *Partial Di erential Equations: Classical Theory with Modern Touch,* Cambridge University Press, 2020.

(C) K. S. Rao, *Introduction to Partial Di erential Equations,* PHI Learning Private Limited, 2013.

Further Readings:

1. F. John, *Partial Di erential Equations (4^{th} ed),* Springer-Verlag, 2009.
2. P. Prasad and R. Ravindran, *Partial Di erential Equations,* New Age International Publishers, 2015.
3. S. Salsa, *Partial Di erential Equations in Action: From Modelling to Theory.* Springer, 2010.
4. A. Tveito and R. Winter, *Introduction to Partial Di erential Equations- A Computational Approach,* Springer-Verlag, 2009.

Essential Textbooks:

(A) R. G. Bartle, *A Modern Theory of Integration,* Amer. Math. Soc., 2001.

(B) Stefan Schwabik and Guoju Ye, *Topics in Banach Space Integration,* World Scienti c, 2005.

Further Readings:

1. R. A. Gordon, *The Integrals of Lebesgue, Denjoy, Perron and Henstock,* Amer. Math. Soc., 1994.
2. R. A. Gordon, *The Use of Tagged Partitions in Elementary Real Analysis,* The American Mathematical Monthly, vol. 105, No. 2 (Feb., 1998), pp. 107-117.
3. R. Henstock, *Theory of Integration,* Butterworths, 1963.
4. D. S. Kurtz and C. W. Schwatz, *Theories of Integration, the Integrals of Riemann, Lebesgue, Henstock-Kurzweil and McShane,* World Scienti c Publishing, 2004.
5. P. Y. Lee and R. Vyborny, *Integral: An Easy Approach after Kurzweil and Henstock,* Cambridge University Press, 2000.
6. T. Y. Lee, *Henstock-Kurzweil Integration on Euclidean spaces,* World Scienti c, 2011.

MAT-MDSE17: Stochastic Processes

Pre-requisites: MAT-MC15 Probability Theory and Random Processes

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: This course introduces stochastic processes like Poisson processes, renewal processes, renewal reward theory. Relation between renewal processes and Markov chains/processes are introduced.

Unit-I

Laws of large numbers, central limit theorem, convergence of random variables, counting processes, Poisson processes, memoryless property, probability density of S_n and joint density of $S_1; : : : ; S_n$, Poisson process as a limit of shrinking Bernoulli processes, combining and splitting Poisson processes, non-homogeneous Poisson processes and order statistics.

Unit-II

Renewal processes: Renewal - reward processes; time averages, Stopping times and Wald's equality, embedded renewals, Little's theorem, ensemble averages, delayed renewal processes.

Unit-III

Finite-state Markov chains: Markov chains, ergodic Markov chains, eigenvalues and eigenvectors of stochastic matrices, Markov chains with rewards.
Countable-state Markov chains: rst-passage times and recurrent states, application of renewal theory and Blackwell's theorem to Markov chains. Birth - death and reversible Markov chains, branching processes.

Unit-IV

Sampled-time approximation to a Markov process, steady-state behavior of irreducible Markov processes, limiting fraction of time in each state, uniformization, reversibility for Markov processes, semi - Markov processes.

Scope: Relevant sections of Chapters 2, 4-7 of (A).

Essential Textbooks:

(A) Robert G. Gallager, *Stochastic processes: theory for applications,* Cambridge University Press, 2013.

Further Readings:

1. A. Grami, *Probability, Random Variables, Statistics, and Random Processes,* JohnWiley & Sons, Inc, 2020.
2. G. R. Grimmett, D. R.Stirzaker, *Probability & Random Processes (3rd ed.),* Oxford University Press, 2001.
3.

MAT-MDSE18: Stochastic Calculus

Pre-requisites: MAT-MC15 Probability Theory and Random Processes

Credits: 4

Contact hours: 60 | **7 hrs/per week (including Tutorials)**

Max. Marks: 100 (Including Internal Assessment-20) | Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: This course will provide the foundation for stochastic calculus. The primary topics covered in the course include Brownian motion, martingales, Itô's lemma, stochastic integration and stochastic di erential equations.

Unit-I

Review of probability theory, random variables, Chebyshev inequality, Borel-Cantelli lemmas, central limit theorems, uctuations, Laplace-DeMoivre theorem. conditional expectation: Least squares method, projection of random variables, conditional Jensen's inequality, Martingales.

Unit-II

Discrete martingale inequalities, Brownian motion, white noice, construction of Brownian motion, one dimensional Wiener process, Levy{Ciesielski construction of Brownian motion, Brownian motion in R^n and applications. The strong Markov property.

Unit-III

Stochastic integrals, Paley{Wiener{Zygmund integral. Itô's integral, approximation by step processes, inde nite Itô Integrals, Itô's formula. Itô's integral in n-dimensions.

Unit-IV

Stochastic di erential equations: Stock prices, Brownian bridge, Langevin's equation. Gronwall's Lemma, existence and uniqueness theorem, properties of solutions.

Essential Textbooks:

(A) L. C. Evans, *An introduction to stochastic di erential equations,* American Mathematical Society, 2012.

Further Readings:

1. O. Calin, *An informal introduction to stochastic calculus with applications,* World Scienti c, 2015.
2. S. N. Cohen and R. J. Elliott, *Stochastic calculus and applications,* Springer, 2015.
3. M. Grigoriu, *Stochastic calculus: applications in science and engineering,* Springer Science & Business Media, 2013.
4. U. Hassler, *Stochastic Processes and Calculus,* Springer Texts in Business and Economics, 2016.
5. F. C. Klebaner,

MAT SEC1: Set Theory

Pre-requisites: MAT-MC3/MC19: Topology and MAT-MC13: Lebesgue Integration

Credits: 4

Contact hours: 60 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: The objective of this course is to discuss the fundamentals of axiomatic set theory, and their importance in diverse branches of mathematics. It will mainly expti mat0yaticghLermelo-Fraenkel axioms, of choice and continuum hypot0ysis, cardinal arithmetic, and a diverse class of non-measurable sets using di erent forms of axiom of choice.

Unit-I

Review of naive set theory, sets, relations, functions, countable sets, cardinality of a set, Schroder-Bernstein theorem,

Unit-IV

Continuum Hypothesis and its Sierpinski's equivalent, measure extension problems, Ulam's theorem, Vitali sets

MAT-MSEC2: Network Analysis

Pre-requisites: MC7: Linear Programming

Credits: 4

Contact hours: 60 7 hrs/per week (including Tutorials)

Max. Marks: 100

Essential Textbooks:

(A) M. S. Bazaraa, J. J. Jarvis and H. D. Sherali, *Linear programming and Network Flows,* John Wiley and Sons, 2004.

(B) L. R. Ford and D. R. Fulkerson, *Flows in Networks,* Princeton University Press,2010.

Further Readings:

1. R. K. Ahuja and T. L. Magnati, *Network Flows-Theory, Algorithm and Applications,* Prentice Hall, N.J., 2005.

MAT-MSEC3: Advanced Optimization Techniques

Pre-requisites: MC7 Linear Programming

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: To acquaint the students with optimization techniques for solving nonlinear programming problems and discuss their theoretical.

Unit-I

Essential Textbooks:

(A) M. S. Bazaraa, J. J. Jarvis and H. D. Sherali, *Linear programming and Network Flows,* John Wiley and Sons, 2004.

(B) P. Venkataraman, *Applied Optimization with MATLAB Programming,* John Wiley and Sons,2009.

Generic Elective Course at Masters Level

(o ered by Mathematics Department) for the students of other departments

MAT-MGE1: Abstract Algebra

Credits: 4

Contact hours: 60 — 7 hrs/per week (including Tutorials)

Max. Marks: 100 (Including Internal Assessment-20) — Time allowed: 3hrs.

- *The question paper will have eight questions, each carrying 16 marks.*
- *There will be two questions from each unit and the candidates will be required to attempt ve, by selecting at least one question from each unit.*

Objective: Nowadays Algebra is considered to be indispensable in Science, Engineering and also has application in Economics and Medicine. Moreover so many very hard and very old problems in Mathematics could be solved using algebra. This course will provide an introduction to four basic structures in algebra viz. Groups, Rings, Fields and Modules.

Unit-I

Group Theory: Symmetries of a Square, The Dihedral Groups, Examples and Properties of groups, Subgroups and Lagrange's Theorem, Normal subgroups and factor groups, Cyclic groups, Symmetric and Alternating groups, Cayley's theorem, Cauchy's theorem, Sylow's theorems.

Unit-II

Ring Theory: Rings, Subrings, Ideals, Homomorphisms, Prime and Maximal Ideals, Unique Factorization Domains and its applications in number theory, Principal Ideal Domains, Euclidean Domains.

Unit-III

Field Theory: Fields, Examples, Algebraic and Transcedental elements. The degree of a eld extension. Adjunction of roots. Splitting elds. Finite elds. Algebraically closed elds, Constructible numbers, Doubling the cube, Trisecting the angle, Squaring theations0brTEcleFinitee T-21543778-26.401 Td [VII

Essential Textbooks:

(A) J. B. Fraleigh,