Department of Mathematical Sciences

Course Structure and Syllabus of Ph.D. course work in Mathematical Sciences

(To be effective from AT 2013)

Course Code	Course Name	L-T-P	CH	Credit
MS 701	Research Methodology in Mathematical Sciences-I	0-1-4	5	3
MS 702	Research Methodology in Mathematical Sciences-II	0-1-4	5	3
*MS 750	Research Methodology in Mathematical Sciences	2-0-2	6	4

**To be effective from SP 2014 replacing MS 701 and MS 702.*

Elective Courses

Course Code	Course Name	L-T-P	CH	CR
MS 753	Magnetohydrodynamics	2-2-0	4	4
MS 754	Programming & Numerical Methods	2-0-2	6	4
MS 755	Ramanujan's Theta Functions and Applications to Number Theory	2-2-0	4	4
MS 756	Topological Structures	2-2-0	4	4
MS 757	Fuzzy Sets & Fuzzy Logic	2-2-0	4	4
MS 758	Algebraic Methods in Operator Theory	2-2-0	4	4
MS 759	Probability Measure, Random Variable and Probability Distribution	2-2-0	4	4
MS 760	Operators on Spaces of Analytic Functions	2-2-0	4	4
MS 761	Theory of Distributions and Sobolov Spaces	2-2-0	4	4
MS 762	Finite Element Methods (FED) for PDEs	2-2-0	4	4
MS 764	Advanced Matrix Theory	2-2-0	4	4
MS 765	Non-Negative matrix Theory	2-2-0	4	4
MS 766	Number Fields and Elliptic Curves	2-2-0	4	4
Ms 767	Theory of Rings and Modules	2-2-0	4	4

L: Lectures T: Tutorials P: Practical CH: Contact Hours (all per week) CR: Credit

*A student has to complete total 16 Credit including Research Methodology in Mathematics (MS-750); any two from the above elective courses**, i.e. Total Credit form elective courses** to be completed by a student = **8,** one CBCT course of CR-4 offered by other departments. Elective courses (as and when offered shall be open as CBCT to other departments.*

Detailed Syllabus

Compulsory Courses

MS 701 Research Methodology in Mathematical Sciences-I (L0-T1-P4-CH5-CR-3)

Unit 1- Introduction
What research basically means, Research need and implication, Brief history and expectation, Research ethics, Plagarism, Prospects of a researcher career, Basic preparation and requirements.

Unit 2- Objectives and types of research
Motivation and objectives, Research methods vs. methodology, Type of research- Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical.

Unit 3- Research Formulation
Defining and formulating research problem, Selecting problem, Necessity of defining the problem, Importance of literature review in defining a problem, Literature review-primary and secondary sources of literature- reviews, treatise, monographs-patents, web as a source-searching the web, critical literature review- identifying gap areas from literature review, Development of working hypothesis. Formulation and steps of the research proposal.

Unit 4- Research design and method
Basic Principles, Need of research design-Feature of a good design, Important concepts relating to reseach design- Observations and Facts, Laws and Theories, Prediction and Explanation, Induction, deduction, development of Models. Research plan development-Exploration, Diagnosis, Experimentation. Experiment and Sample designs.

Unit 5- Data collection and Analysis
Observation and collection of data- primary and secondary data, Methods of collection of data- Sampling methods, Data processing and analising strategies, Data analysis with statistical methods, Hypothesis testing, Generalization and Interpretations

Text Books:

1. C. R. Kothari, *Research Methodology*, 2nd Ed. Wiley Eastern, New Delhi, 1985.
2. Anthony, M., Graziano, A. M. and Raulin, M.L., *Research Methods: A Process of Inquiry*, Allyn and Bacon, 2009.

Reference Book

1. John W Best, V. Kahn, *Research in Education*, 8th Ed. PHI Publication, 1998.
3. Ranjit Kumar, *Research Methodology-A step by step guide for beginners*, 2nd Ed. Pearson Education, 2005.

MS 702: Research Methodology in Mathematical Sciences -II (L0-T1-P4-CH5-CR-3)

Unit 1- Computer Applications
Utility software- Public liscense and Proprietary Software, Data analysing software (PSPP), Typesetting software (LaTex), Software for plagiarism (Similarity-tester).

Unit 2-Reporting and thesis writting
Structure and components of scientific reports- Poster, Journal paper, Technical report and Thesis, Book and book chapters. Significance of different steps in preperation-Layout, Structure and Language of different reports, Illustrations and Tables, Bibliography, Referencing and Foot note, End note. Oral presentation-planning, Preperation, Practice, Making presentation-use of Audio-visual aid, Importance of effective communication.

Unit 3 – Documentation and research output accessment
Research communication and publication, Impact factor and citation, Scientific Citation Index and Extended list, H-index and i-10 index, Patent and royalty.

Unit 4 – Application of result and ethics
Impacts- acdemic, environmental, industrial, market, social. Ethical issues, ethical commitees, commercialization, copyright, royalty, intelectual property rights, reproduction and published materials, plagarism, reproducibility and accountability of results.

Text Books:

1. C. R. Kothari, *Research Methodology*, 2nd Ed. Wiley Eastern, New Delhi, 1985.
2. Anthony, M., Graziano, A. M. and Raulin, M.L., *Research Methods: A Process of Inquiry*, Allyn and Bacon, 2009.

Reference Book

1. John W Best, V. Kahn, *Research in Education*, 8th Ed. PHI Publication, 1998.
2. K.N. Krishna swami and others, *Management Research Methodology-Integration of principles, methods and Techniques*, 1st Ed. Pearson Education, 2009.

MS 750: Research Methodology in Mathematical Sciences (L2-T0-P2-CH6-CR-4)

Unit 1- Introduction
What research basically means, Research need and implication, Brief history and expectation, Research ethics, Plagarism, Prospects of a researcher career, Basic preparation and requirements.

Unit 2- Objectives and types of research
Motivation and objectives, Research methods vs. methodology, Type of research- Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical.

Unit 3- Research Formulation
Defining and formulating research problem, Selecting problem, Necessity of defining the problem, Importance of literature review in defining a problem, Literature review-primary and secondary sources of literature- reviews, treatise, monographs-patents, web as a source-searching the web, critical literature review- identifying gap areas from literature review, Development of working hypothesis. Formulation and steps of the research proposal.

Unit 4- Research design and method
Basic Principles, Need of research design-Feature of a good design, Important concepts relating to reseach design- Observations and Facts, Laws and Theories, Prediction and Explanation, Induction, deduction, development of Models. Research plan development-Exploration, Diagnosis, Experimentation. Experiment and Sample designs.

Unit 5- Computer Applications
Utility software- Public liscense and Proprietary Software, Data anlysing software, Typesetting software, Mathematical software. Software for plagarism.

Unit 6- Data collection and Analysis
Observation and collection of data- primary and secondary data, Methods of collection of data- Sampling methods, Data processing and analising strategies, Data analysis with statistical methods, Hypothesis testing, Generalization and Interpretations

Unit 7-Reporting and thesis writting
Structure and components of scientific reports- Poster, Journal paper, Technical report and Thesis, Book and book chapters. Significance of different steps in preperation-Layout, Structure and Language of different reports, Illustrations and Tables, Bibliography, Referencing and Foot note, End note. Oral presentation-planning, Preperation, Practice, Making presentation-use of Audio-visual aid, Importance of effective communication.

Unit 8 – Documentation and research output accessment
Research communication and publication, Impact factor and citation, Scientific Citation Index and Extended list, H-index and i-10 index, Patent and royalty.

Unit 9 – Application of result and ethics
Impacts- acdemic, environmental, industrial, market, social. Ethical issues, ethical commitees, commercialization, copyright, royalty, intelectual property rights, reproduction and published materials, plagarism, reproducibility and accountability of results.

Text Books:

1. C. R. Kothari, *Research Methodology*, 2nd Ed. Wiley Eastern, New Delhi, 1985.
2. Anthony, M., Graziano, A. M. and Raulin, M.L., *Research Methods: A Process of Inquiry*, Allyn and Bacon, 2009.

Reference Book

1. John W Best, V. Kahn, *Research in Education*, 8th Ed. PHI Publication, 1998.
2. K.N. Krishna Swami and others, *Management Research Methodology-Integration of principles, methods and Techniques*, 1st Ed. Pearson Education, 2009.
3. Ranjit Kumar, *Research Methodology-A step by step guide for beginners*, 2nd Ed. Pearson Education, 2005.

Elective Courses

(Any two are to be chosen by a student)

MS 753 Magnetohydrodynamics (L2-T2-P0-CH4-CR4)

Unit-1
The MHD approximations, The Kinematic aspects of MHD.

Unit-2
The magnetic force and its effects.

Unit -3
Linear MHD, Non-dimensional numbers in MHD,

Unit-4
Alfrin's theorem and some consequences of Alfrin's theorem.

Unit-5
Stability of MHD Flows, turbulance in MHD.

Textbook(s)

1. Shercliff, J. A. A Text Book of Magnetohydrodynamics (Pergamon, New York, 1965).

Reference book(s)

1. Ferraro, V. C. A. & Plumpton, C. An Introduction to Magneto-fluid Mechanics (Oxford University Press, 1961).
2. Pai, S. I. Magnetohydrodynamics and Magnetogasdynamics (PN, 1955).

MS 754 Programming and Numerical Methods (L2-T0-P2-CH6-CR4)

Unit-1
Approximation and algorithms.

Unit-2
Interpolation: Lagrange interpolation, finite differences, iterated and inverse interpolation, Hermite interpolation.

Unit-3
Numerical integration: Newton-Cotes formulas, Gaussian quadrature, composite quadrature formulas, adaptive integration.

Unit-4
Functional approximation, least squares approximation, minimum-maximum error techniques. Chebyshev polynomials.

Unit-5
Solution of non-linear equations: functional iteration, bisection, secant, Newton-Raphson. Solving problems with FORTRAN 77.

Unit-6
Solution of linear systems: direct methods- Gauss elimination, LU decomposition matrix inversion. Solving problems with FORTRAN 77.

Unit-7
Iterative methods: Jacobi Method, Gauss-Seidel method, SOR method. Eigenvalue problems: power, inverse power method. Solving problems with FORTRAN 77.

Unit-8
Numerical solutions of ODE's: Taylor series, Euler and Runge-Kutta methods. Solving problems with FORTRAN 77.

Textbook(s)

1. F. B. Hilderbrand, Introduction to Numerical Analysis (Tata McGraw Hill, New Delhi, 1974).
2. S. S. Sastry, Introductory methods of Numerical Analysis (Prentice Hall of India, New Delhi, 1977).

Reference book(s)

1. M. K. Jain, S. R. K. Iyengar, R. K. Jain, Numerical methods, Problems and solutions, (New Age International (P) Ltd., 1996).

MS 755 Ramanujan's Theta Functions & Applications to Number Theory

(L2-T2-P0-CH4-CR4)

Unit-1

Ramanujan's general theta-function, special cases and their relations, *q*-series and infinite products, Jacobi triple product identity.

Unit-2

Schröter's formulae and theta-function identities and Ramanujan's Modular equations.

Unit-3

Class invariants, Evaluation of class invariants, Explicit values of theta-functions

Unit-4

Ramanujan's continued fractions and explicit values.

Unit-5

Applications of theta-functions and modular equations to the theory of partitions.

Unit-6

Ramanujan's famous congruences for the partition function, Rogers-Ramanujan-type functions and partition theoretic interpretations.

Textbook(s)

1. Berndt, B. C. *Number Theory in the Spirit of Ramanujan* (AMS, 2006).
2. Andrews, George E., *The Theory of Partitions (A*ddition-Wesley, Reading, MA, 1976).

Reference book(s)

1. Berndt, Bruce C., *Ramanujan's Notebooks,* Part III, IV and V (Springer, 1991, 1994, 1998).
2. Whittaker, E. T. and Wilson, G. N., *A Course in Modern Analysis (*Cambridge University Press, Cambridge, 1966. Indian edition is published by Universal Book Stall, New Delhi, 1991).
3. Agarwal, R. P**.**, *Resonance of Ramanujan's Mathematics,* Vol. I & II (New Age International (P) Limited, New Delhi, 1996).
4. Hardy, G. H., *Ramanujan (*AMS-Chelsea, New York 1999).

MS 756 Topological Structures (L2-T2-P0-CH4-CR4)

Unit-1

Basics of point set topology

Unit-2

Uniform structures, uniform continuity, completeness and completions, metrizability of uniform spaces; different uniform structures in topology,

Unit-3

Paracompactness, countably paracompact space, weakly and strongly paracompact space, metrization results;

Unit-4

Dimension theory, basic properties of three dimension functions ind, Ind and dim, properties of dim, the imbedding theorem.

Textbook(s)

1. Willard, S., *Topology* (Addision -Wesley, Reading, 1970)
2. Kelley, J.L.,*Topology (*Graduate texts in Mathematics, Vol. 27, Springer, 1991).

Reference Book(s)

1. Bourbaki,N., *Elements of Mathematics: General Toplogy*, Vols I & II (Springer-Verlag, 1988).
1. Engelking, R., *Topology (*Heldermann Verlag, 1989).
2. Munkers, J.R., Topology (Pearson Rducation Inc., 2000)

MS 757 Fuzzy sets and Fuzzy Logic (L2-T2-P0-CH4-CR4)

Unit-1
Fuzzy sets - basic definitions, alpha-level sets, convex fuzzy sets, basic operations on fuzzy sets, types of fuzzy sets, cartesian products, algebraic products, bounded sum and difference, t-norms and t-conorms.

Unit-2
The extension principle - the Zadeh's extension principle, image and inverse image of fuzzy sets, fuzzy numbers, elements of fuzzy arithmetic.

Unit-3
Fuzzy relations and fuzzy graphs, composition of fuzzy relations, min-max composition and its properties, fuzzy equivalence relations, fuzzy graphs.

Unit-4
Fuzzy logic, fuzzy propositions, fuzzy quantifiers, linguistic variables, inference from conditional fuzzy propositions, compositional rule of inference.

Unit-5
Approximate reasoning - an overview of fuzzy expert systems, fuzzy implications and their selection, multi-conditional approximate reasoning, role of fuzzy relation equation. Rough sets, intuitionistic fuzzy sets and applications

Textbook(s)

1. G. J. Klir and B. Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications (*Prentice Hall of India, New Delhi, 1997).
2. H. J. Zimmermann, *Fuzzy set theory and its Applications (*Allied publishers Ltd., New Delhi, 1991).

Reference book(s)

1. D. Dubois and H. Prade, *Fuzzy sets and systems: theory and applications (*Academic Press, New York, 1980).
2. A. Kandel, F*uzzy mathematical techniques with applications (*Addison-Wesley, Reading, Mass, 1986).
3. A. Kaufmann, and M. M. Gupta, *Introduction to fuzzy arithmetic: theory and applications* (Van Nostrand Reinhold, New York, 1985).
4. B. Kosko, *Fuzzy thinking: the new science of fuzzy logic* (Flamingo, 1994).

MS 758 Algebraic Methods in Operator Theory (L2-T2-P0-CH4-CR4)

Unit-1
Fredholm operators, Semi-Fredholm operators, index of a Fredholm (semi-Fredholm) operator.

Unit-2
Weighted shifts and their norm and spectral radii.

Unit-3
Normaloid, convexoid and spectraloid operators **.**

Unit-4
Toeplitz operators **.**

Unit-5
Transitive, Reductive,Reflexive operator algebras.

Unit-6
Strictly cyclic and cyclic operator algebras, triangular and quasi triangular operator algebras.

Unit-7
The Hardy Spaces, Beurling's Theorem and its extensions, The Inner-Outer Factorization of Functions in H^2.

Textbook(s)

1. R. G. Douglas, *Banach Algebra Techniques in Operator Theory* (Academic Press 1972).
2. Conway, J. B., *A course in Operator Theory* (AMS., GSM Vol. 21, 1999).
3. Abramovich, Y. A. and Aliprantis, C. D., *An Invitation to Operator Theory* (AMS, GSM Vol. 50, 2002).

Reference book(s)

1. H. Radjavi and P. Rosenthal**,** *Invariant Subspaces,* Springer Verlag, 1973.
2. D. A. Herrero**,** *Approximation of Hilbert Space Operators I*, Pitman Advanced Publishing Program, 1982.
3. D. A. Herrero, *Approximation of Hilbert Space Operators II*, Pitman Advanced Publishing Program, 1984.
4. P. R. Halmos, *A Hilbert Space Problem Book*, III Edn. D. Van Nostrand Co., 1974.
5. Bernard Beauzamy, *Introduction to Operator Theory and Invariant Subspaces*, North Holland, 1987.
6. M. Rosenblum and J. Rovnyak, *Hardy Classes and Operator Theory*, Dover Publications, Inc., 1997.

MS 759 Probability Measure, Random Variable and Probabilty Distribution

(L2-T2-P0-CH4-CR4)

Unit-1

Definition of probability measure on a sample space, Lebesgue measure, measurable sets, measurable functions and random variables. Probability distribution of a random variable.

Unit-2

Lebesgue Integral and Expectation of a random variable and Extension theorem.

Unit-3

Probability measures defined on complete, separable metric spaces. The concept of tightness, Weak convergence, Portmanteau theorem.

Unit-4

Prohorov's theorem. Weiner Measure, Brownian Bridge.

Unit-5

Sequences of random variables, almost sure convergence, convergence in probability and convergence in law of distributions. Laws of Large numbers, Central limit theorems, Berry-Esseen theorem. Empirical process and Glivenko-Cantelli theorem.

Textbook(s)

1. Billingsley, P**.** *Convergence in Probability Measures*, (John Wiley and Sons, 1999).
2. Chow and Teicher, *Probability Theory, Independence, Interexchangeabilities, Martingales*, (Springer-Verlag, 1997).

Reference book(s)

1. Ash, R. B. *Probability and Measure Theory, Second Edition* (Harcourt/Academic Press, 2000).
2. Feller, W. *An Introduction to Probability Theory and Its Applications*, Vol. II (John Wiley and Sons, 1965).

MS 760: Operators on Spaces of Analytic Functions (L2-T2-P0-CH4-CR4)

Unit-1

Preliminaries in Operator Theory : Operators on Banach Spaces and Hilbert Spaces, Compact operators, Schatten class operators, Hilbert-Schmidt operators.

Unit-2

Theory of Bergman Spaces : Bergman type projections, Bergman metric, Atomic decomposition, The Bloch space.

Unit-3

A study of Hardy spaces H^p with special reference to the Hardy-Hilbert space H^2, Hankel and Toeplitz operators on the H^2 space.

Unit-4

Hankel and Toeplitz operators on the Bergman space, Composition operators on the Hardy and Bergman spaces.

Textbook(s)

1. Ruben A. Martinez-Avendano and Peter Rosenthal, *An introduction to Operators on the Hardy-Hilbert Space* (Springer, 2007).
2. Kehe Zhu, *Operator Theory in Function Spaces*, Second Edition (Marcel Dekker, 2007).
3. John B. Conway, *A course in Operator Theory* (American Mathematical Society, 1999).

Reference book(s)

1. Peter L. Duren, Alexander Schuster, *Bergman Spaces* (American Mathematical Society, 2004).
2. Haakan Hedenmalm, Boris Korenblum, Kehe Zhu, *Theory of Bergman Spaces* (Springer, 2000).
3. Ronald G. Douglas, *Banach Algebra Techniques in Operator Theory*, Second Edition, (Springer, 1998).
4. John B. Conway, *A course in Functional Analysis* (Springer-Verlag, 1997).
5. Kenneth Hoffman, *Banach Spaces of Analytic Functions* (Dover, 1988).

MS 761 Theory of Distribution and Sobolev Spaces (L2-T2-P0-CH4-CR4)

Unit -1

Inner Measure, Outer Measure, Measurable Sets, Lebesgue Measure, Measurable functions, Lebesgue Integration, L_p spaces.

Unit -2

Test functions and distribution, Generalised derivatives, Some operations on distribution, The Fourier transform, The inverse Fourier transform.

Unit -3

Sobolev norms and associated spaces, Extension theorems, Inclusion relations and Sbolev's inequality, Negative norms and Duality, Fractional order Sobolev space, trace Theorems

Unit -4

Interpolation, Bounds for the interpolation error, Inverse estimates, Interpolation of non-smooth functions

Textbook(s)

1. B. Daya Reddy, *Introductory Functional Analysis : With Applications to Boundary Value Problems and Finite Elements* (Springer, 1997).
2. Robert S. Strichartz , *A guide to Distribution Theory and Fourier Transforms*, Studies in Advanced Mathematics (CRC Press, USA ,1994).
3. S. Kesavan, *Topics in Functional Analysis and Applications (*Wiley Eastern Limited, 1989).

Reference book(s)

1. R. A. Adams and John J. F. Fournier, *Sobolev Spaces*, (Academic Press, 2003).
2. Soo-Bong Chae, *Lebesgue Integration*, (Springer-Verlag, 1994).
3. Elliot H. Lieb and Michel Loss, *Analysis (*Narosa Publishing House, New Delhi, 1997).

MS 762 Finite Element Methods (FEM) for PDEs (L2-T2-P0-CH4-CR4)

Unit -1

Variational formulation**,** Lax-Milgram Theorem**,** Regularity estimates**,** Construction of Finite Element Space, Finite Element Approximation to Elliptic BVP, Convergence Analysis

Unit -2

Variational formulation, Semi-discretization, Discretization in space and time, The backward Euler and Crank Nicolson methods, Error Analysis

Unit-3

Variational formulation, Semi-discretization, Fully discretization, Error Analysis.

Effect of Numerical Quadrature: Curved Elements, Numerical quadrature, Isoparametric Finite Elements.

Unit -4

Introduction to Mixed FEM, Discontinuous Galerkin Method

Textbook(s)

1. S.C. Brenner and L.R. Scott, *The Mathematical Theory of Finite Element Methods*, (Springer-Verlag, 1994).
2. J. N. Reddy, An *Introduction to the Finite Element Method* (McGraw-Hill, Inc., 1993).
3. Stig Larsson and Vidar Thomée, *Partial Differential Equations with Numerical Methods*, (Springer, 2005).

Reference book(s)

1. P. G. Ciarlet, *The Finite Element Method for Elliptic Problems* (North Holland, Amsterdam, 2002)
2. V. Thomee, *Galerkin Finite Element Method for Parabolic Problems*, (Springer- Verlag, 1997).
3. C. Johnson, *Numerical Solution of Partial Differential Equations by Finite Element Method* (Dover Publications, 2008).

MS 764 Advanced Matrix Theory (L2-T2-P0-CH4-CR4)

Prerequisites: MS 403 Linear Algebra

Unit-1
Review of Linear Algebra

Unit-2
Unitary matrices, Unitary equivalence, Normal matrices, Schur's theorem.

Unit-3
Hermitian and symmetric matrices, variational characterization of eigenvalues , application of variational characterizations.

Unit-4
Positive definite matrices, Positive semidefinite matrices.

Unit-5
Singular value decomposition, Schur complement.

Textbook(s)

1. Horn, R. and Johnson, C. R., *Matrix Analysis (*Cambridge University Press, Cambridge, 1985).
2. Meyer, Carl D. *Matrix Analysis and Applied Linear Algebra (*SIAM, 2000).

Reference book(s)

1. Bellman, Richard, *Introduction to Matrix Analysis (*McGRAW-HILL BOOK COMPANY, 1960).
2. Horn, R. A. and Johnson C. R., *Topics in Matrix Analysis* (Cambridge University Press, Cambridge, 1999 (Reprint)).

MS 765 Non-Negative Matrix Theory ***(L2-T2-P0-CH4-CR4)***

Prerequisites: MS 403 Linear Algebra

Unit-1

Nonnegative matrices, positive matrices, Irreducible matrices, Reducible matrices.

Unit-2

Perron's theorem, Primitive matrices.

Unit-3

Stochastic matrices, Graphs and nonnegative matrices.

Unit-4

Inverse eigenvalue problem.

Textbook(s)

1. Minc, Henryk, *Nonnegative Matrices* (John Wiley and Sons, 1988).
2. Horn, R. and Johnson, C. R., *Matrix analysis* (Cambridge University Press, Cambridge, 1985).

Reference book(s)

1. Berman and Plemmons, *Nonnegative Matrices in the Mathematical Sciences*, (SIAM, 1994).
2. Bapat and Raghavan, *Nonnegative Matrices and Applications* (CUP, 1997).

MS 766 Number Fields and Elliptic Curves (L2-T2-P0-CH4-CR4)

Unit-1
Number fields and their rings of integers, Prime decomposition in number rings.

Unit-2
The ideal class group and the unit group, Dirichlet's Unit Theorem, Dedekind zeta function and the class number formula, Class Numbers of Quadratic Fields and Cyclotomic fields.

Unit-3
Introduction to algebraic curves, singular and non-singular curves, Mordell-Weil group law on elliptic curve, explicit formulas for group law.

Unit-4
Points of finite order on elliptic curves and Nagell-Lutz theorem.

Unit-5
Mordell's theorem, rank of elliptic curves.

Unit-6
Elliptic curves over finite fields, Complex multiplication.

Textbook(s)

1. Marcus, D. A. *Number Fields*, 3th edition (Springer-Verlag, 2009).
2. Stewart, I. N. & Tall, D. *Algebraic Number Theory and Fermat's Last Theorem*, 3rd edition (A K Peters Ltd., 2000).
3. Silverman, J. H. & Tate, J. *Rational Points On Elliptic Curves* (Springer- Verlag, 2005).

Reference book(s)

1. Mollin, R. A. *Algebraic Number Theory* (CRC Press, 1999).
2. Esmonde, J & Murty, R. M. *Problems in Algebraic Number Theory* (GTM Vol. 190, Springer-Verlag, 2000).
3. Knapp, A. W. *Elliptic Curves* (Princeton University Press, 1993).

MS 767 Theory of Rings and Modules (L2-T2-P0-CH4-CR4)

Unit-1
Idempotent, Nilpotent and Von Neumann regular elements, Chain conditions.

Unit-2
Artinian & Noetherian rings and modules, Exact sequences

Unit-3
Essential (Large) and Superfluous (Small) submodules, Relative complement, Closed submodule, Semisimple rings and modules

Unit-4
Jacobson radical, Jacobson semisimple (semiprimitive) rings, Local, Semilocal rings.

Unit-5
Decomposition theorems (Fittings', Peirce etc.), Corner rings, Uniform submodules and finite dimensionality.

Unit-6
Projective and Injective submodules.

Textbook(s)

1. Lam, T. Y. *A First course in Noncommutative rings*, 2nd edition (Springer, 2001).
2. Goodearl, K. R. *Ring Theory (*Marcel Dekker, Inc. 1976).
3. Anderson, F. W. and Fuller, K. R. *Rings and Categories of Modules*, 2nd edition (Springer-Verlag, 1992).

Reference book(s)

1. Musili, C. *Introduction to Rings and Modules*, 2nd revised edition (Narosa Publishing House, 1994).
2. Lambek, J. *Lectures on Rings and Modules*, 3rd edition *(*AMS Chelsea Publishing, 2009).
3. Burton, D.M. *A first course in rings and ideals* (Addison-Wesley, 1970).
4. Barshay, J. *Topics in ring theory* (W.A. Benjamin Publ. 1969).
5. Chatters, A.W. and Hajarnavis, C.R. *Rings with chain condition* (Pitman, 1980).